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FOCUS



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Q&A

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THE AMAZING SCIENCE OF DOGS

How to build a starship

FOOTBALL'S TECH FUTURE

SPECIAL REPORT

THE Origin OF Life

New clues to where it started and how it evolved



Action cams

Tested to destruction!

Stephen Baxter

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06 >

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Spy tech

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Welcome

June 2012

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Already a subscriber? Turn to page 30 for an exclusive feature on the frontiers of particle physics



Without doubt it's one of the biggest mysteries of our time, foxing great minds for generations. There are more questions than answers, and as

many theories as experts. The question is: why do football referees get so many decisions wrong?

It's an issue that's bound to crop up again when Euro 2012 begins on 8 June. I for one hate to see teams (okay, England) denied by a dodgy decision. It isn't referees' fault. Football hasn't embraced new technology, unlike virtually every other major sport. So in frustration, we decided to find out how much more beautiful the game would be if technology were used – not just to prevent unfair penalties but to enhance the experience for players and spectators alike. Nic Fleming's feature kicks off on page 58.

The other big mystery we're looking at this issue is, as you've probably guessed, the origin of life. Over the last few months, several fascinating studies have been published. They've proposed various mechanisms for how life began and where it got started. There's still no definitive answer, and there may never be, but the

research has profound implications – not just for life on Earth, but for the rest of the Universe as well.

Speaking of which, how much of the cosmos will we eventually explore? It largely depends on the spacecraft at our disposal, which is why the US Defense Advanced Research Projects Agency (DARPA) recently set up its 100 Year Starship study. With sci-fi flick *Prometheus* coming soon to cinemas, it seemed the perfect time to ponder long-range space travel – begin your journey on page 46.

From outer space to inner, and you may have seen experimental psychologist Prof Bruce Hood present the 2011 Royal Institution Christmas lectures on BBC TV. We catch up with Bruce to find out his latest theories of what makes you *you* on page 56.

And last but not least, the computer geek in me is rather excited by the prospect of Windows 8 being released later this year. Turn to page 88 to find out how it could change the technology landscape.

Until next issue,

Graham

What I've found out this month

- A solar sail spanning hundreds of kilometres would be needed to power a spaceship to the stars (p49)
- Our ancient, common ancestor could have emerged in the mid-Atlantic (p39)
- There's a wealth of archaeological 'digs' to be done in the Solar System (p24)

Experts



James Benford

A physicist at California-based Microwave Sciences, James is co-editing a book on the 100 Year Starship. On p46, he turns his attention to the future of long-range space exploration.



Doctor Peter Bradshaw

Dr Bradshaw is an expert on anthrozoology – the study of human-animal interactions – and the author of *In Defence Of Dogs*. On p66, he looks at how we've shaped man's best friend.



Professor Chris Stringer

Prof Stringer is one of the world's foremost experts in the study of early man, and the author of *The Origin Of Our Species*. On page 23, he addresses this month's 'Burning Question'.



Emma Davies

A chemist by training and an expert in food science, Emma is a regular contributor to our Update section. On page 20, she looks at the bizarre story of deadly mushrooms in China.



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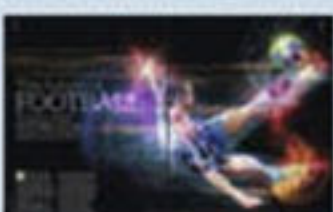
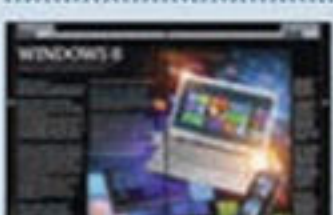
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How did life on our spinning ball of rock first emerge?

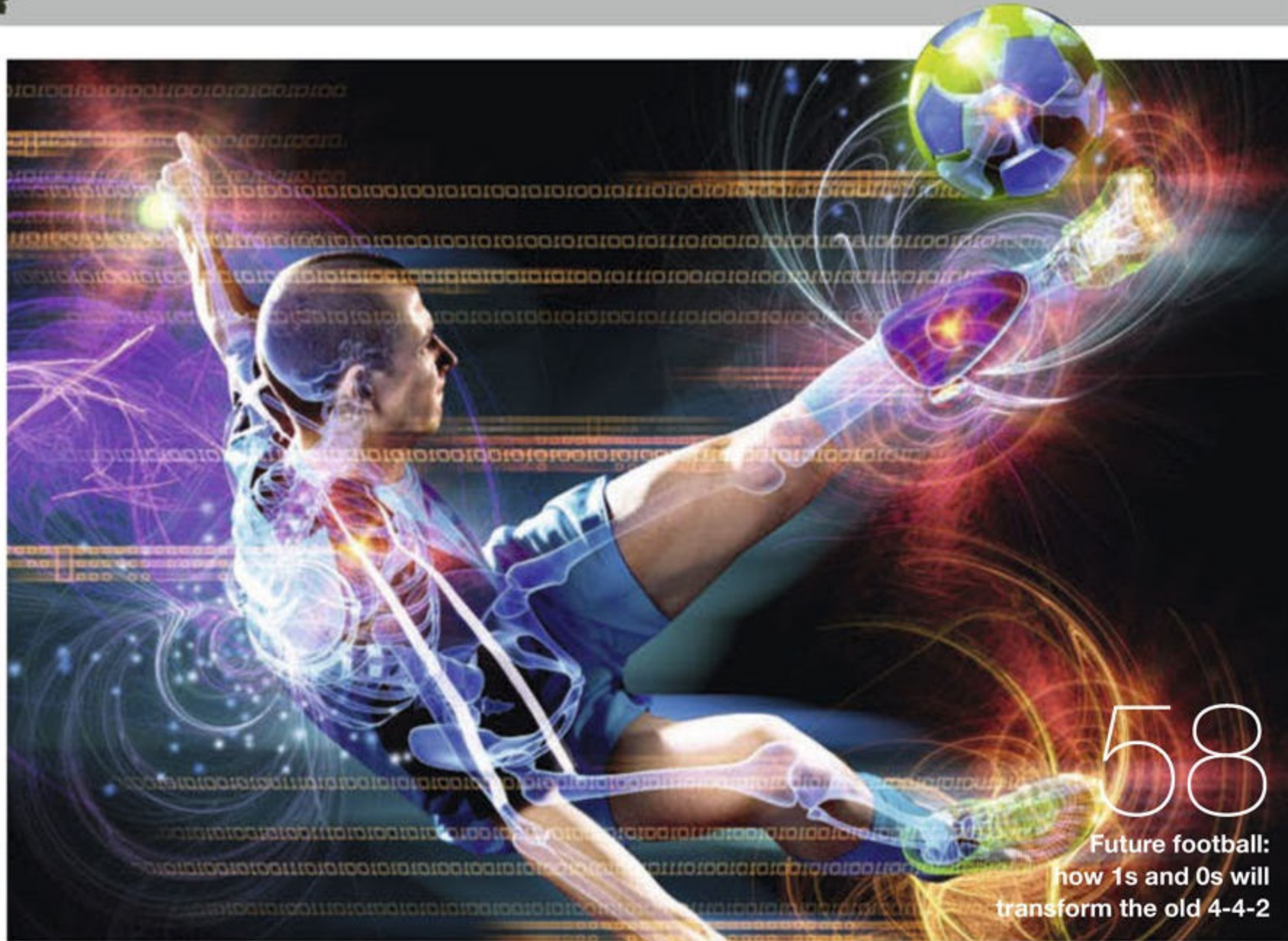


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Dogs: how the wolf evolved to become man's best friend

"The gap between us and chimps is small. But the transition from CO₂ and rocks to living things is very difficult"

Evolutionary biologist Prof Bill Martin, *The origin of life*, p33



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Future football:
how 1s and 0s will
transform the old 4-4-2



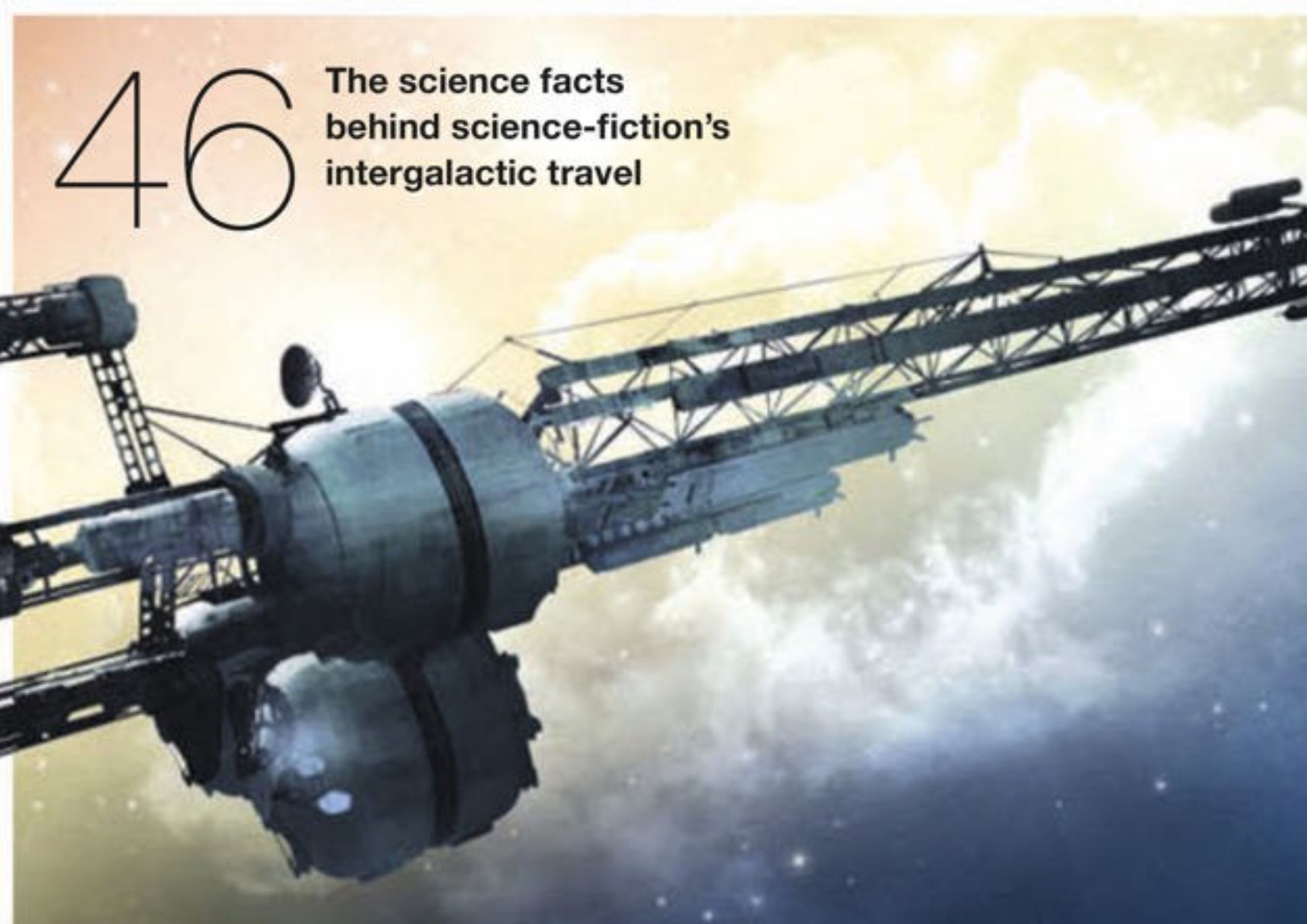
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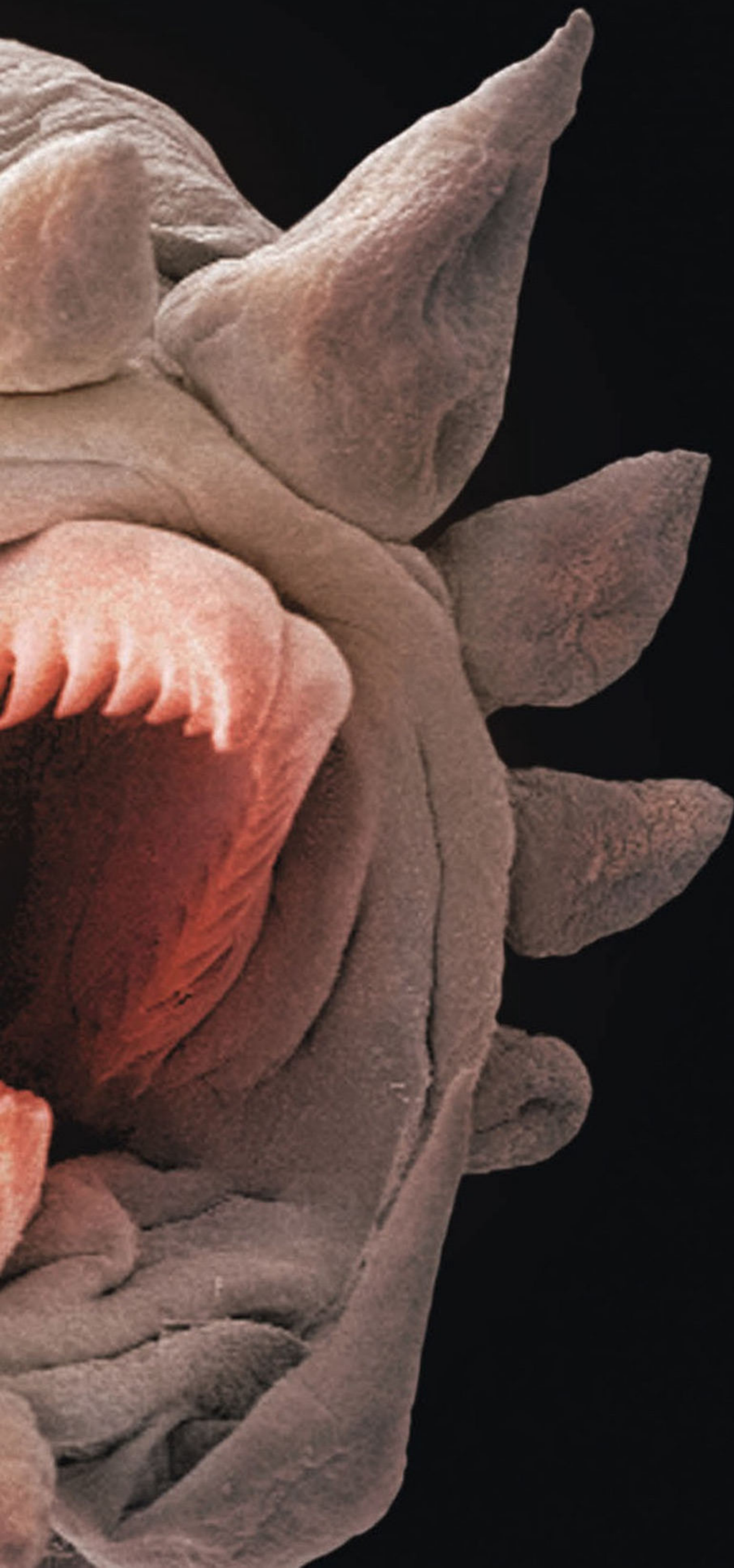
The Blue room

The afternoon sun illuminates an ice cave in the Skaftafell region of southeast Iceland. The cave formed underneath the Svínafellsjökull glacier, which slowly moves down the slopes of Öraefajökull, Iceland's tallest active volcano. As it moves, some of the ice encounters rock, and the resulting friction and the relative warmth of the rock cause melting. Added to this, meltwater from the glacier's surface works its way through ice cracks to the cave beneath. In the warmer summer months, there's enough meltwater to flow through the cave.

"The ripples on the ceiling and walls are called 'scallops' and are sculpted by the flow of water," says Dr George Veni, Executive Director of the National Cave and Karst Research Institute in the US. "Glacier caves are geologically young features – some do not exist for more than a year or two before collapsing."

Air bubbles are squeezed out of the ice as it moves. This allows light to penetrate, causing the ice to appear blue because it absorbs more light at the red end of the spectrum.





Alien from the deep

Like the fearsome predator in *Alien*, the jaws of this deep-sea worm are usually hidden inside its mouth. But come feeding time, the worm's serrated jaws extend out to grab prey or scrape bacteria from 'mats' near its home at hydrothermal vents.

This species of scale worm, *Lepidionotopodium piscisae*, is adapted to survive at depths of up to 3km in the northern Pacific Ocean. The worm's body – 3cm long and 1cm wide – can withstand almost 300 times atmospheric pressure. The triangular structures around the mouth, called palps, help the worm detect its prey, although it's not known whether this process occurs through touch or chemical signals.

"In general we don't have such information for deep sea species," says biologist Dr Florence Pradillon of the IFREMER oceanography institute in Brest, France. "We just make guesses because they're comparable to species in the coastal environment."





Cloud city

These intimidating clouds, climbing over the skyscrapers of Panama City Beach in Florida, are known as orographic strati. The balmy air passing over the Gulf of Mexico is laden with water vapour which, when it hits the apartment blocks on the shore, quickly rises to the colder, thinner atmosphere above. As the air reaches the chillier heights it condenses, forming the clouds seen enveloping the buildings in this picture.

"You can see these kinds of clouds in the UK," says Helen Chivers, a forecaster for the Met Office. "In late spring through to summer, air carries water up the cliffs of Dover, forming localised low clouds while the surrounding area remains clear."

The clouds tend to remain stationary, the wind constantly regenerating the formation.

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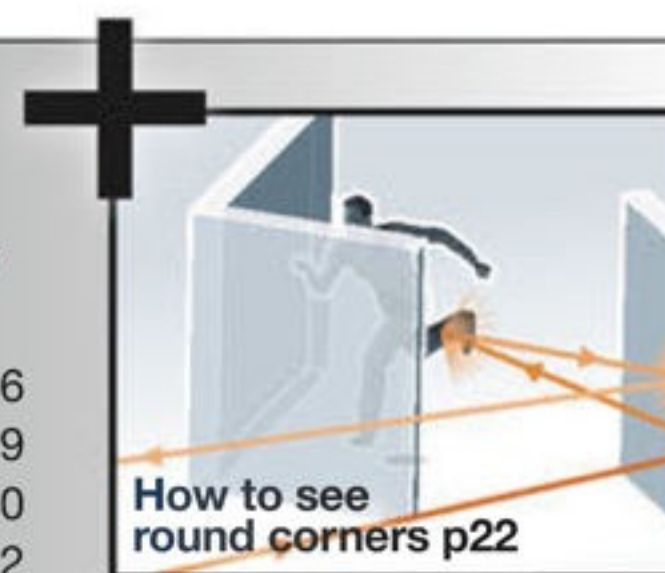
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At the heart of the image



Need to know

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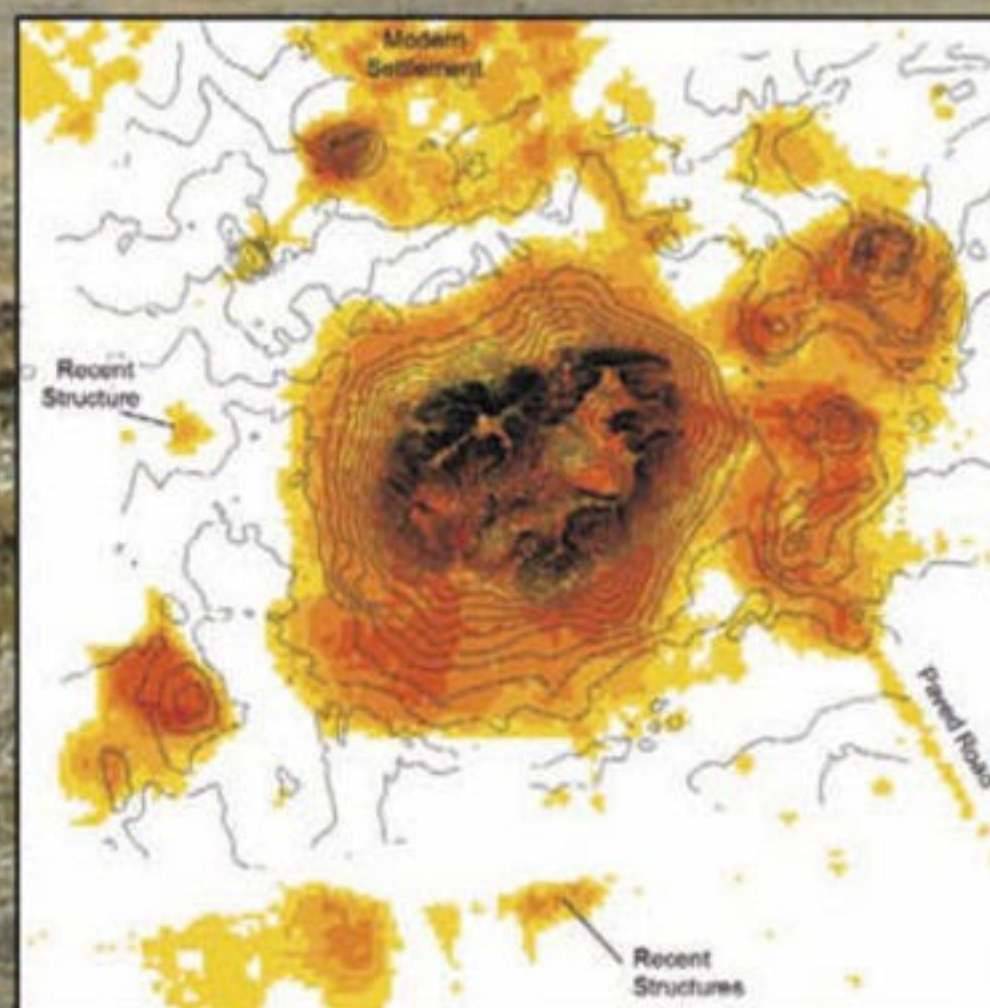
Automated archaeology

Satellite identifies thousands of ancient settlements in just one day

Desktop dig

Archaeologists are increasingly able to make discoveries without getting their hands dirty, by scouring satellite images. Some techniques, like the one developed by Ur and Menze, are highly sophisticated. But Google Earth is enabling archaeology to be carried out using a desktop computer. In 2011 it was announced that almost 2,000 potential archaeological sites had been found in Saudi Arabia using the virtual world map.

"Every six months I read about someone else who has used Google Earth to find an archaeological site," says Ur. "It's a good thing, because as cities are growing and agriculture is intensified, it has a destructive effect on global cultural heritage. Methods like this have the ability to quickly document what's there."



The map (inset) reveals the likelihood of ancient settlements in Tell Brak, Syria

Swapping trowels and maps for satellites and algorithms is enabling archaeologists to search thousands of square kilometres of land for lost towns and villages overnight.

The technique relies on the fact that the mud bricks used to build homes in many locations leave their mark on the landscape in the form of 'anthrosols', which have a lighter appearance than natural soil. Several images of the same patch of land taken by the ASTER satellite, each focused on a different part of the electromagnetic spectrum, are used to pick out different characteristics of the anthrosols. When data from these different wavelengths is combined using an algorithm, it provides an accurate prediction of whether an archaeological site lies beneath.

In early tests using the method on a 23,000 square kilometre (14,300 square miles) area in northern Syria, 14,000 settlements were discovered. Buried in sand and soil over time, the villages date from the late Neolithic right up to the recent past.

"In the past, we archaeologists worked on the ground and either studied small areas intensively, or large areas with low intensity. We looked out the window of a Jeep to spot sites, and would only find the biggest settlements," says Dr Jason Ur, the Harvard archaeologist behind the technique. "This new method combines the intensity of the small search with the wide coverage of a broad one."

In this way, the outlines of towns and villages can be traced out. "The algorithm runs on powerful computers overnight," says Ur, who developed the technique with MIT computer scientist Bjoern Menze. When the outlines of settlements are combined with an elevation map, an estimate of each village's volume is generated. This gives an indication of its longevity, as villages would expand outward and upward as they grew.

"I'm now planning a research project for Iraq's Kurdistan region," Ur says, "but the algorithm should work well in similar environments elsewhere, such as the Niger Valley and coastal South America."

Little man, big bang



These two vast clouds of gas and dust were thrown out by a stellar explosion over 100 years ago. But now NASA's Hubble Space Telescope has captured the most detailed image of the Homunculus (Latin for 'little man') Nebula yet.

At the centre of the nebula are two stars, one orbiting the other, which erupted in the 1830s – their glow peaking in 1843. To this day, it's still not clear what caused this outburst of the Eta

Carinae star system. This new photograph, which consists of ultraviolet and visible light images, clearly shows that rather than being thrown out in a uniform pattern, the gas and dust form a dumbbell shape. Together, the two clouds are 1,000 times the width of our Solar System.

Studying the Homunculus Nebula's chemical composition – by analysing the different wavelengths of light emitted – has been telling.

"There is a lot more nitrogen and helium than there would be around a normal star," says Professor Kris Davidson of the University of Minnesota. "This is what happens when a star is near the end of its lifetime."

This makes Eta Carinae a prime candidate to explode as a supernova in the near future – though in astronomy, 'near future' could still mean in a million years' time...

37
million

bacteria can be kicked up into the air every hour by just one person, say Yale University scientists.

1 yoctogram

or 10^{-24} g is the smallest weight that can be detected by new scales built in Spain. Atoms or molecules are placed on nanotubes that vibrate at different frequencies according to their mass.

5

times the width of the Earth is the size of a tornado spotted on the Sun's surface by NASA's Solar Dynamics Observatory.

Neutrinos *don't* break the speed limit...

Physicists at the ICARUS experiment in Italy measured the time it took for seven neutrinos to reach a liquid argon-filled detector after they were released from the CERN particle physics lab in Switzerland, 730km (450 miles) away. They found that neutrinos travel at roughly the speed of light, but no faster. The ICARUS experiment is located in the same lab within the Gran Sasso mountain in central Italy as the OPERA

experiment that produced the results which flew in the face of Einstein's special theory of relativity.

The final nail in the coffin for faster-than-light, or superluminal, neutrinos may well come in May, when all four of the experiments in Gran Sasso – OPERA, ICARUS, Borexino and LDV – will time beams of the particles released from CERN.

...but they could **revolutionise communication**



The Tevatron
particle accelerator
in Illinois, USA

Neutrinos have been used to send a message for the first time. Although it's still early days, the ability of these subatomic particles to travel vast distances through almost any material makes them an exciting alternative to radio waves, which are easily blocked by mountains and oceans.

Physicists sent a simple message through 240 metres of stone. These humble first steps show that a completely new means of communication is feasible that would enable links which are not currently possible. To test the system, physicists in the US converted the word 'neutrino' into binary code, a series of 1's and 0's. A beam of neutrinos from the Tevatron particle accelerator at the Fermi National Accelerator Lab near Chicago was then modulated, with a pulse of neutrinos corresponding to a '1' and no neutrinos corresponding to a '0'. The resulting signal was received at the MINERvA neutrino detector in a cavern 100 metres underground, where it was translated back into letters.

Neutrinos ('little neutral ones' in Italian), have zero electric charge and an almost non-existent mass, so they rarely

interact with matter: they can pass right through Earth.

They could provide a means to communicate with nuclear submarines, since radio waves don't travel well through salt water. They could also be used to send messages to a rover or base on the far side of another planet.

"In cases where large amounts of matter would need to be penetrated to allow communication, neutrinos could save the day," says Professor Kevin McFarland, a physicist at the University of Rochester, which led the research.

But the 'neutrinophone' technology still needs more work to be of practical use. The very property that makes neutrinos such an exciting prospect in communications, their ability to penetrate matter, also makes them extremely difficult to detect. The MINERvA detector weighs 170 tonnes, not a practical possibility aboard a sub. "The neutrino beams we currently make are not sufficiently intense to send a lengthy message and are difficult to point at a moving target," says McFarland. "But increasing the beam intensity is one of the main areas that's being investigated right now."

INSIGHT

Nuclear fusion**What's that?**

It's when light atomic nuclei, such as hydrogen nuclei, join up to form a heavier one. When this happens, the combined mass is less than the sum of the individual nuclei, and energy is released. It's this process that has been touted as an alternative power source to nuclear fission, in which atoms are split.

Why aren't we using it as a source of energy today?

The protons in different hydrogen nuclei will repel one another because they have the same charge (positive). It takes temperatures of around 100,000,000°C and high pressures to overcome that repulsion. Creating those conditions is proving difficult.

Why is fusion in the news now?

One way of producing those conditions is to aim an intense laser at the fusion fuel. At the National Ignition Facility (NIF) at the Lawrence Livermore National Laboratory in California, they've focused 192 lasers to produce one with a power of 1.875 megajoules. That's a record and it brings us closer to ignition.

What's ignition?

It's when sufficient energy is generated to overcome the repulsion between protons, and more energy is produced from fusion than is contained in the laser pulse.

Was fusion achieved?

It's thought the laser would have been powerful enough, but since this was merely a test there was no fuel in the target chamber. It is hoped ignition will be achieved before the end of September. The next step would be a commercial power plant.



ROUND UP

This month's top science stories from around the globe

SPACE

Asteroid could 'skim' Earth

A 50m space rock that has only recently been spotted could pass within 24,000km (14,900 miles) of Earth – closer than many satellites – in February 2013. The asteroid 2012 DA14's flight path was calculated by astronomers at the La Sagra Sky Survey observatory in southeast Spain. But subsequent calculations by other astronomers appear to show that the rock will only pass within 63,000km (39,000 miles), much further than the 35,000km (22,000 miles) operating altitude of most satellites.

GENETICS

Exercise affects your DNA

A good workout not only makes your muscles stronger, it also affects your genes. Physiologists at the Karolinska Institute in Stockholm took biopsies from the muscles of volunteers who had been riding exercise bikes. They found that genes involved with energy production had been altered. The coating, or methylation, around promoter regions – sections of DNA that control the activity of specific genes – had been removed. The change is thought to boost the work capacity of muscle.

TECHNOLOGY

Laser zaps ink off pages

Using a hand-held laser, it may soon be possible to re-use paper that's previously been printed on. Engineers in the University of Cambridge's Low Carbon Materials Processing Group have found a way to remove toner ink from a page by heating it. "The key is to find a laser energy level high enough to vaporise the toner, but low enough to avoid damaging the paper," says David Leal-Ayala. "At the moment we've only demonstrated the concept," he says. "The next step is to build a prototype."

GEOLOGY

Detroit: a geologist's dream

The many abandoned factories and homes in Detroit have turned the US city into a natural lab. Geologist Dr Jeffrey Howard at Wayne State University is using vacant land to study soil formation – particularly the weathering of rocky and mineral objects. Knowing when a building was demolished provides an accurate date at which soil started to develop – something that's impossible to know in nature. The research is already showing similarities between the weathering of chunks of mortar and iron nails, and that seen in natural rocks and minerals.

ENVIRONMENT

Coral resists global warming

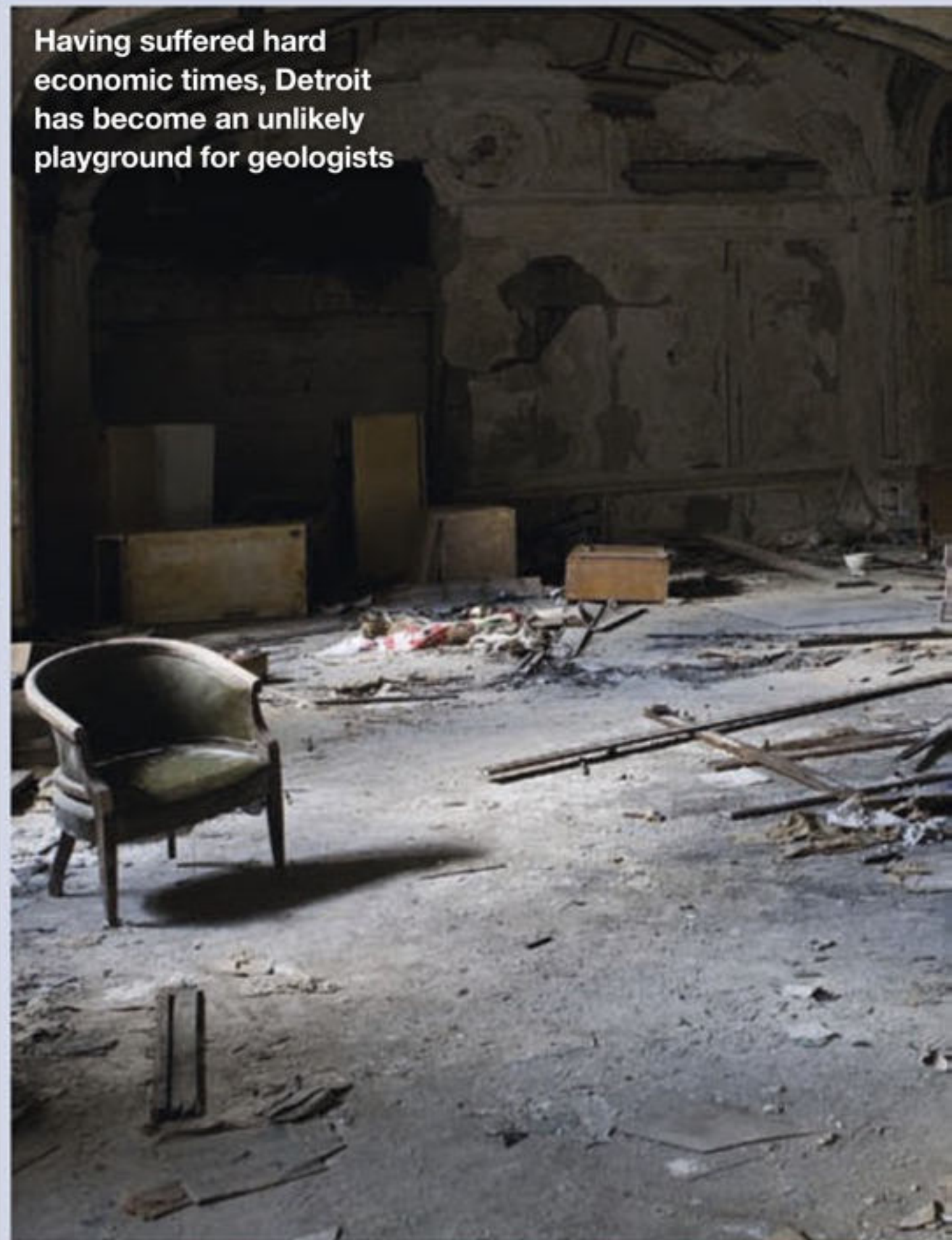
It's become a symbol of global warming: corals turning white and dying off as sea temperatures rise. But a team of marine biologists that includes British scientists has found evidence that corals may adapt to warmer waters. Colonies of the *Acropora* coral in Singapore and Malaysia that had bleached in 1998 were healthy after the waters warmed again in 2010. It's not clear whether it's the coral itself that adapts, or the algae zooxanthellae, which is expelled from the coral when it bleaches.

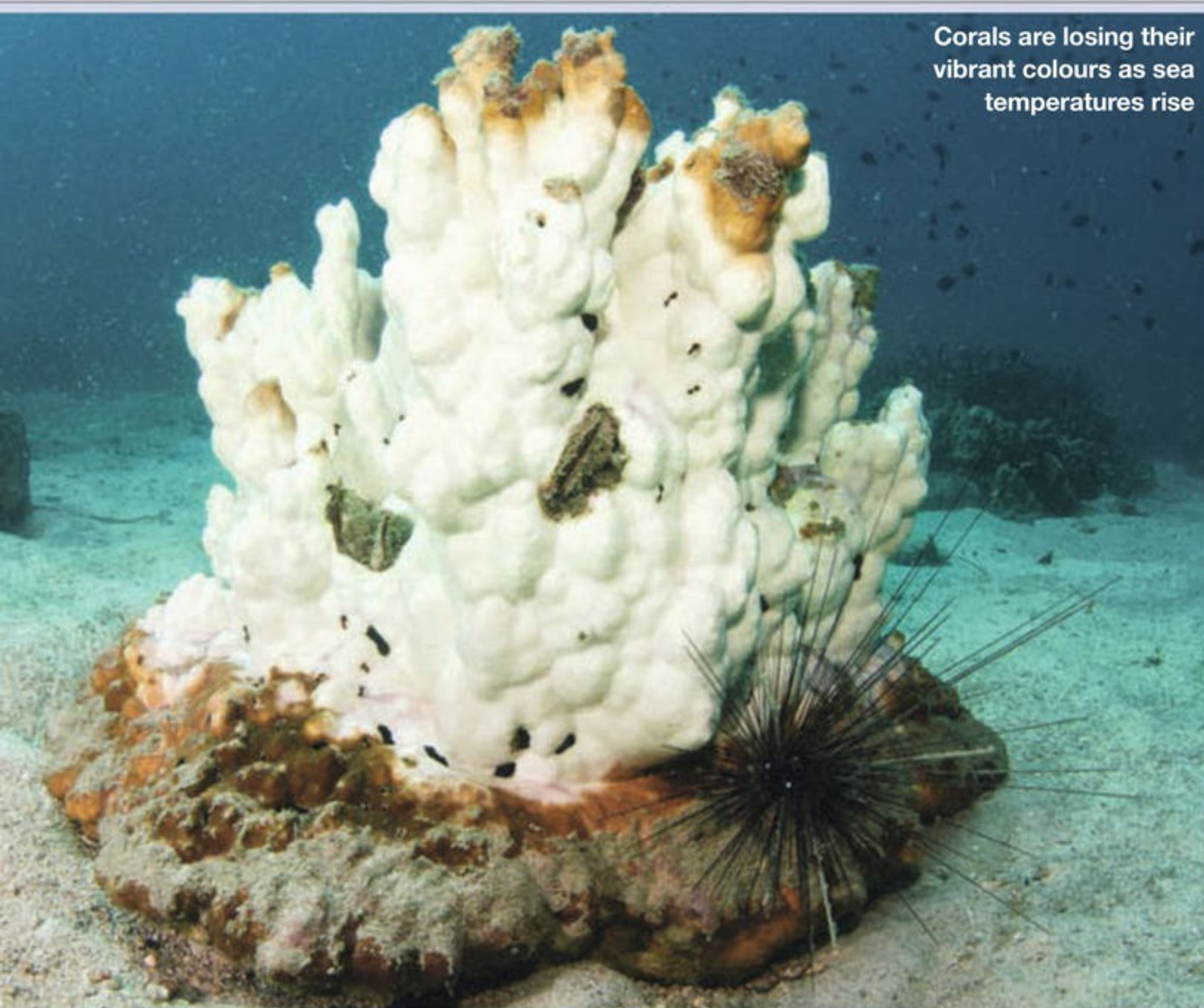
COMPUTING

Silicon sleuths

Columbo step aside – humble computers are more effective at detecting liars than experienced interrogators. In tests at the University of Buffalo in the US an automated system that analysed the eye movements of volunteer interviewees in video recordings correctly identified when someone was lying or telling the truth 82 per cent of the time. Interrogators typically have a 65 per cent success rate. The system focused on the rate of blinking and the frequency people shifted their gaze.

Having suffered hard economic times, Detroit has become an unlikely playground for geologists





Corals are losing their vibrant colours as sea temperatures rise



NEUROSCIENCE

Brain's decision centre found

At times of anxiety and depression, we tend to make negative decisions – choosing options that present fewer problems but less rewards. Now neuroscientists at MIT in the US have found the source of these negative thoughts. They offered monkeys a choice between large rewards that came with an annoying air puff and small rewards without one. They were more likely to avoid the puff and take a smaller treat when the anterior cingulate cortex was stimulated, showing that area of the brain was responsible.

PHYSIOLOGY

Bat flight conserves energy

A bat's wing flap is even more energy efficient than had been thought. The conventional wisdom has been that bats draw their wings in on the upstroke to reduce drag. But scientists at Brown University in the US have found that by pulling their wings in, bats only use 65 per cent of the energy required to change the wings' movement than they would otherwise. Video of bats flying, shot at 1,000 frames per second, and measurements of the mass of different portions of the wing, were used to make the calculations.



A mighty predatory dinosaur discovered by palaeontologists in northeastern China would have had a feathery coat – similar to that of a modern bird's chick.

It's been known for a decade that some small dinosaurs had feathers, but weighing at over a tonne, *Yutyrannus huali* was 40 times the weight of the largest previously known feathered dinosaur.

In the middle part of the early Cretaceous period, when *Yutyrannus* was alive, average temperatures where it lived were about 10°C. So the coat may have been an adaptation for cold conditions.

Preserved *T. rex* skin has scales rather than feathers but the discovery of feathers on *Yutyrannus* by Chinese and Canadian scientists opens up the possibility that the king of the dinosaurs may have had some feathers.

NEWS IN BRIEF

A team of "undersea pros" paid by billionaire Amazon.com founder Jeff Bezos have found the rockets that propelled Neil Armstrong on his historic journey to the Moon. Deep-sea sonar was used to discover the locations of the F-1 engines, which dropped into the Atlantic Ocean minutes after Apollo 11's launch in 1969. Bezos, who acknowledges the rockets are NASA's property, says he hopes to raise one or more of the engines from their final resting place, 4,200 metres (over two miles) beneath the ocean surface. It's then hoped that they can go on public display.

Caterpillars of the Large White butterfly (*Pieris brassicae*) vomit on creatures likely to attack them. Now biologists at Bristol and Liverpool universities have found that they are less likely to puke if they are part of a large group. While vomiting makes larvae a less enticing foodstuff, the loss of food resulting from doing so also slows their growth. In a large group, it therefore makes sense for individuals to rely on their neighbour's regurgitation rather than lose their own lunch.

Cosmonauts will land on the surface of the Moon by 2030, according to a leaked strategy document from Russia's space agency Roscosmos. Although plans for space exploration have been announced by Russia in the past, this is the first time a firm target has been set.

A male giraffe's age can be estimated by looking at the colour of its coat. It's been known for a while that they develop darker coats as they age, but by studying records of Thornicroft giraffes, biologist Prof Fred Bercovitch from Kyoto University has been able to identify the exact timing of colour changes. From this, the age of a giraffe can be determined. It's thought that the darkening is due to higher testosterone levels.

Spy gloves could leave false prints

The polymer's surface can change pattern on demand

Rubber gloves that can produce intricate, fingerprint-like surface patterns at the flick of a switch might sound like something Q would give to James Bond, but they could soon be a reality. Engineers in the US have created a polymer that can change its surface texture on demand, before changing back again.

As well as hypothetical 'spy gloves', the material could be used in everything from shoe soles to medical implants. "There are many instances where you'd want to be able to change a surface from one that is rough to slippery and back again," says Xuanhe Zhao,

Assistant Professor of Mechanical Engineering and Materials Science at Duke University.

The shape-shifting happens when a voltage is applied to the polymer, and engineers have managed to create surface patterns. "The patterns we have created in the lab include circles and straight and curved lines, which are the basic elements of fingerprints," says Zhao.

The material was constructed by bonding a polymer layer that deforms onto a more rigid one. This stiff surface was coated with a metal layer that acts as an electrode. The flexible polymer was also coated with an electrode

that can deform, leaving it sandwiched between two electrodes.

When a voltage was applied between them, an electric field developed in the polymer and it began to fold in on itself, forming surface features such as ridges and creases. Pre-stretching the polymer before the voltage is switched on enables these features to be aligned in a particular direction. When the voltage is switched off, the pattern disappears.

Another application could be medical implants that release a drug when the polymer's surface changes.



Killer mushroom is bang to rights

The mushroom now known to be the cause of some mysterious deaths in southwest China appears to have an unusual way of killing its victims: causing a dramatic drop in blood sugar.

More than 400 people had died from 'Yunnan sudden death syndrome', some reportedly mid-sentence. In 2010 these deaths were linked to a small white mushroom, *Trogia venenata*, pictured, which had been consumed by the victims. Now, chemists at the Chinese Academy of Sciences have identified three toxic substances in the

fungus – two amino acids, plus a known toxin called γ -guanidinobutyric acid.

The toxins only have a mild effect on the heart, but one possibility is that the amino acids could reduce the body's ability to produce the energy-containing chemicals ATP and glucose. Mice given a mushroom extract suddenly develop a low blood sugar level.

The detective work continues. "Next, we will collect more mushrooms and pay attention to some of the smaller peptides that we haven't focused on before," says research leader Dr Ji-Kai Liu.

LOOK BACK

75 YEARS AGO
Joseph-Armand Bombardier is granted a patent for a vehicle with a caterpillar track on the back and steerable skis on the front – today called a snowmobile.

20 YEARS AGO
The first baboon-to-human liver transplant is carried out at the University of Pittsburgh Medical Center.

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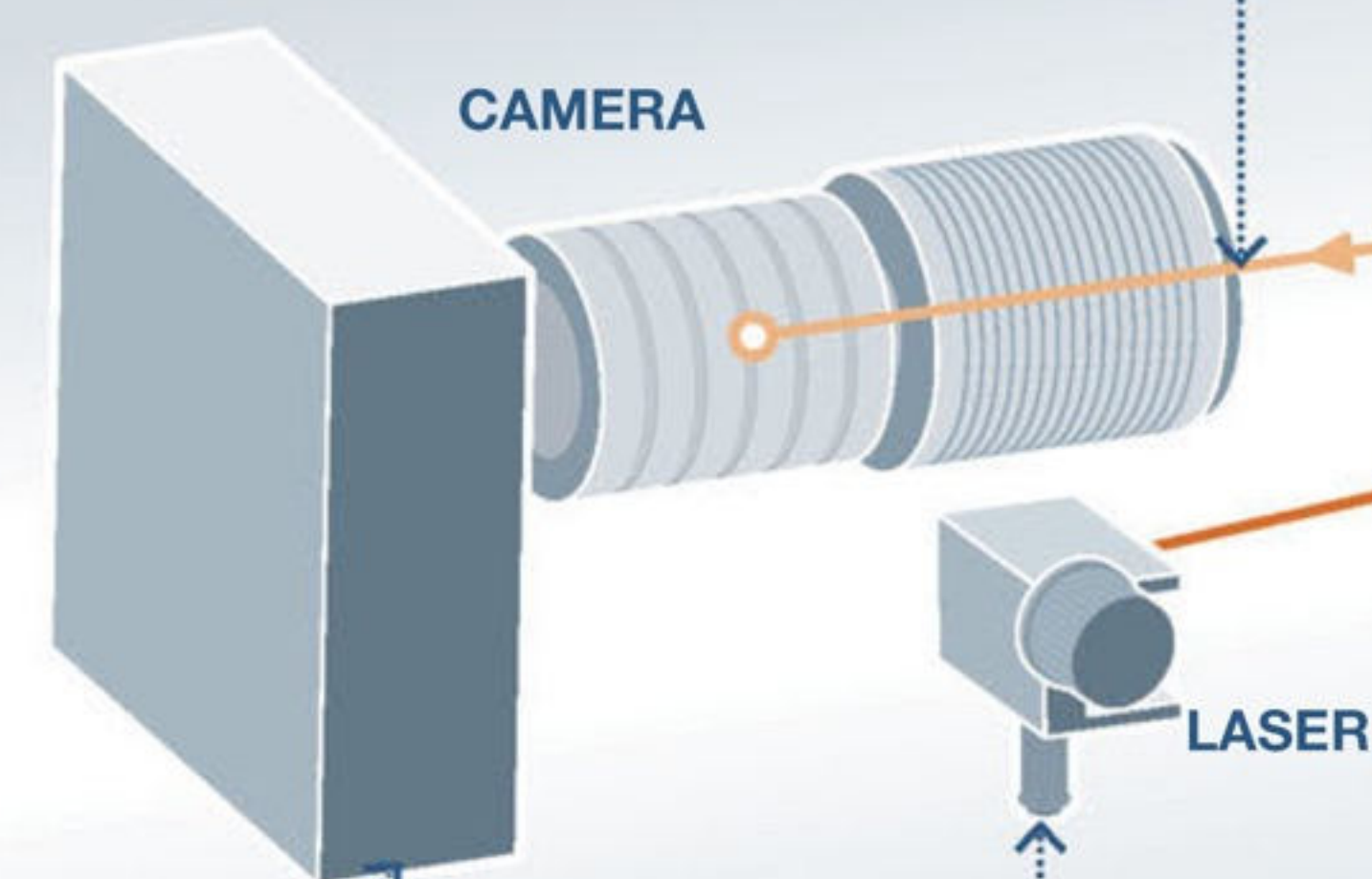
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How to see round corners

3. Deflected photons that hit parts of the hidden object closest to the wall reach a camera quicker than those hitting parts that are further away.



4. The camera can record the different arrival times between two photons, even when they are only 0.2 picoseconds apart.

1. A laser pulse is fired at a wall behind the hidden object and the light particles, or photons, are scattered.

2. Some of the scattered photons hit the hidden object and bounce off it. A small number of these reach the wall, again bouncing off it.

5. The whole process is repeated 60 times, with the laser moving slightly in position each time. An algorithm uses the arrival times of the photons to build up a reconstruction of the hidden object.

If you're a soldier hiding behind the corner of a building, wondering whether there's someone on the other side, being able to see around solid objects could save your life. Now scientists at the Massachusetts Institute of Technology (MIT) in the US have found a way to do just that.

A normal camera can only see objects that are in its direct line of sight. To get round this

problem, physicists bounced a laser off a wall onto a hidden object and measured the time it took for photons deflected by the object to reach a camera. By recording the different arrival times of the photons they were able to build up an image of the hidden object's contours.

"Surgeons could use this technology to look around organs and see hidden spots

without using invasive probes," says Otkrist Gupta, a graduate student at MIT who has been involved in the research. "Or we could use it for search and rescue to find hidden and trapped survivors."

The process currently takes several minutes to build up an outline picture of a hidden object, but it is hoped to reduce it to less than 10 seconds.

...and finally

Dinos didn't go bang

It's official – dinosaur corpses did not explode. This had been proposed as an explanation for the fact that the bones of ichthyosaurs, marine reptiles that lived 245 to 90 million years ago, are often found scattered. But manometers placed inside 100 human corpses (a good stand-in for similarly sized ichthyosaurs) have shown that the pressure of gas in a putrefied body is insufficient. It's now thought the gases would have caused dead ichthyosaurs to float, and that water scattered the bones.

Licking each other clean boosts ants' immune systems



Ant infections licked

It's behaviour we associate with dogs, but ants also employ the power of the lick to enhance their personal hygiene. If an ant is infected with fungal spores the infected individual is licked clean rather than being shunned by its fellow colony residents, scientists at the Institute of Science and Technology Austria have discovered. This activity increases the infected ant's chances of survival, while genes involved with anti-fungal defences in the surrounding *Lasius neglectus* ants are also activated in the process.



Will we ever completely understand the origins of modern humans?

How many times have you seen news reports claiming that a new fossil discovery changes everything we know about how we, modern humans, came to be? The latest example of the syndrome has been prompted by the discovery of the 'Red Deer Cave people', who are thought to have lived about 13,000 years ago in southwest China and enjoyed a diet rich in venison. Australian and Chinese scientists have found their fossils in two caves, prompting headlines like 'Red Deer Cave people may be new species of human'.

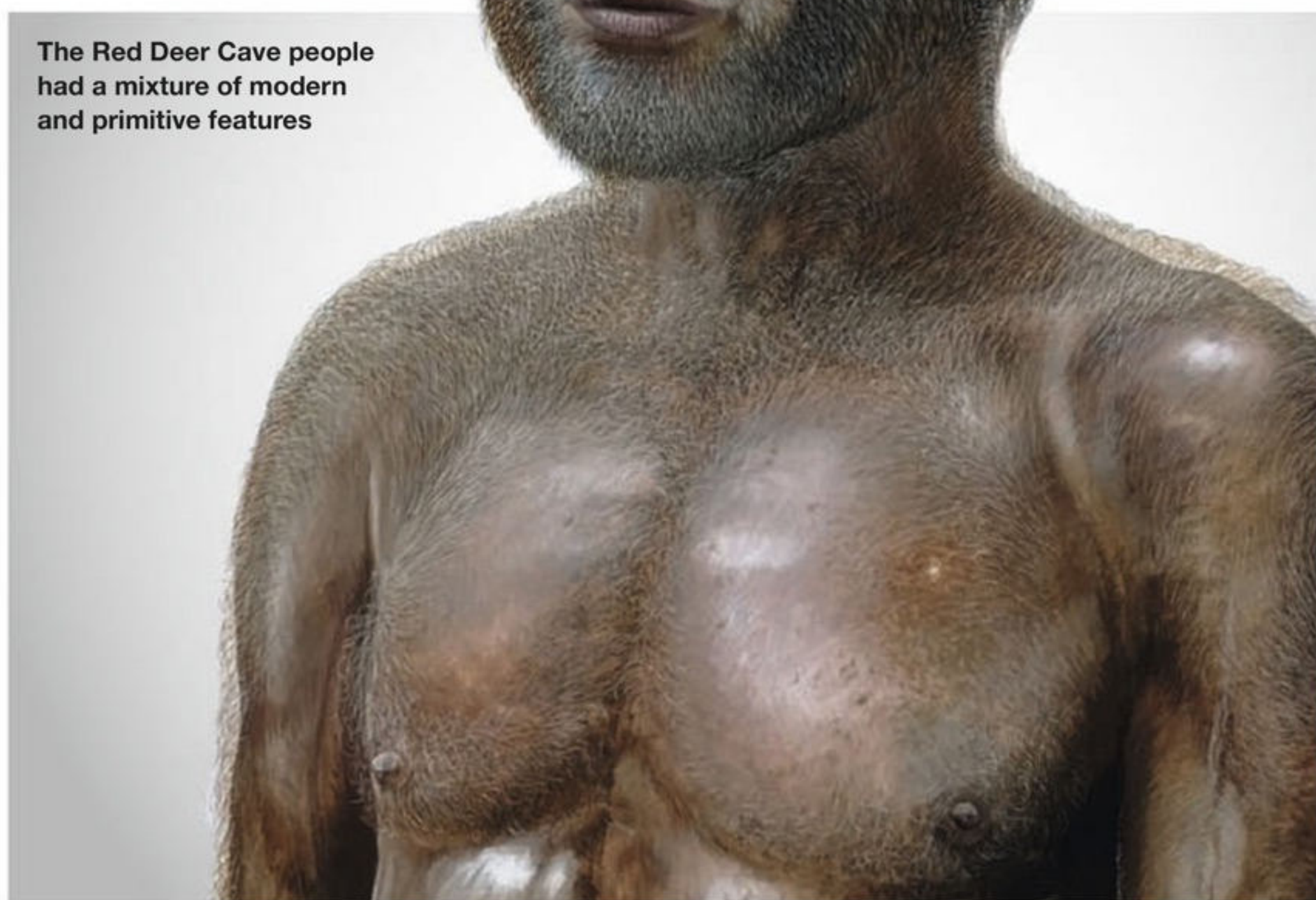
To the public, it must seem like the more we find, the more confusing the story of our origins becomes – that every new discovery rewrites what we know. If the Red Deer Cave people *were* a new species, they would be yet another branch of our evolutionary tree, requiring it to be redrawn yet again. 'Scientists stumped by prehistoric human', claimed *The Sydney Morning Herald*.

But we're not getting more confused. In some cases, like this one, the problem lies in how these things are reported. The original paper on the cave people, published in *PLoS ONE*, correctly classified the fossils as simply being a new form of *Homo sapiens* based on clear modern human features such as the retracted face and rounded skull. In other words, they're not a completely new species, just a variation on ours that still had some primitive features such as jutting jaws. So no major rewriting of history is required.

With each new discovery, what is becoming ever more apparent is that our evolution was not a simple progression of species leading only to us. Instead there were many natural 'experiments' over millions of years in how to become 'human', and we are the last survivors of these. Human evolution was more like a bush than a ladder, and we now know that some of the branches even intertwined, when different lines interbred with each other. But how clear a picture do we have of the whole story: of exactly how we came to be?

The answer is that we know quite a lot about parts of the story, but very little about other parts, and we will never have all the evidence we need.

The Red Deer Cave people had a mixture of modern and primitive features



"We know quite a lot about parts of the story, but very little about other parts"

The best we can hope to do is to get ever nearer to the truth about our origins as we build up an ever more detailed picture.

We can imagine the story of our origins as a large and complex 4-dimensional jigsaw puzzle (the fourth dimension being time): one where we have patches with quite a lot of pieces (such as for Europe in the last 35,000 years and East Africa between 1.5 and 3.5 million years ago), but large patches with very little in the way of pieces (such as West Africa and India). We are much more likely to be surprised when something turns up in one of the large gaps than in an area where we already have reasonable coverage.

For example, we are now able to fill those gaps through means other than fossil discoveries. While the fossils from Denisova Cave in southern

Siberia are too fragmentary to tell us where they fit into our evolution based on their anatomy, their whole genome has now been reconstructed so we can already say that they were more closely related to the Neanderthals than to us.

The quality of our data has also improved greatly in the 40 years I have been involved in research on human evolution. While a century ago it could be claimed that you could pack up the fossil evidence for human evolution in a suitcase, you would need a good many suitcases now.

But as long as the headlines lead the public on, it will always seem as though the boffins are baffled yet again!

WHAT DO YOU THINK?

Does the media jump the gun when it comes to new claims about man's origins?
post@sciencefocus.com



The Analyst Robert Matthews

A great deal of medical research is pointless – some of it's been done already!

Whenever I pick up the latest issues of research journals, I quickly skim the contents in the hope of finding something interesting – and usually end up disappointed. It's then that I ask myself a question: why did anybody bother doing this stuff?

Esoteric doesn't begin to describe most of it, but I suspect that 'pointless' does. It's not the done thing to cast aspersions on other people's research (especially when one of your own papers was, ahem, devoted to the physics of why toast usually lands butter side down). But I recently sat in on a lecture given by someone who has no such qualms: Sir Iain Chalmers.

Don't be fooled by the knighthood – Sir Iain is a natural-born troublemaker who has devoted his career to asking awkward questions about science. As co-ordinator of the James Lind Initiative, he's an expert

in assessing medical research – and he's not impressed by what he sees.

Giving the annual Wolfson Haldane lecture in Oxford, he stuck the boot into researchers who conducted 'me too' studies simply because they couldn't be fagged to find out what was known before they started. This is more than just a waste of time and money. Clinical trials involve patients, and Sir Iain showed how the failure of researchers to check what was already known led to thousands of patients taking part in pointless studies of a drug proven to work years earlier. As half of the patients in a clinical trial are given an alternative treatment, that means thousands of patients were being denied access to a proven therapy, with potentially fatal consequences.

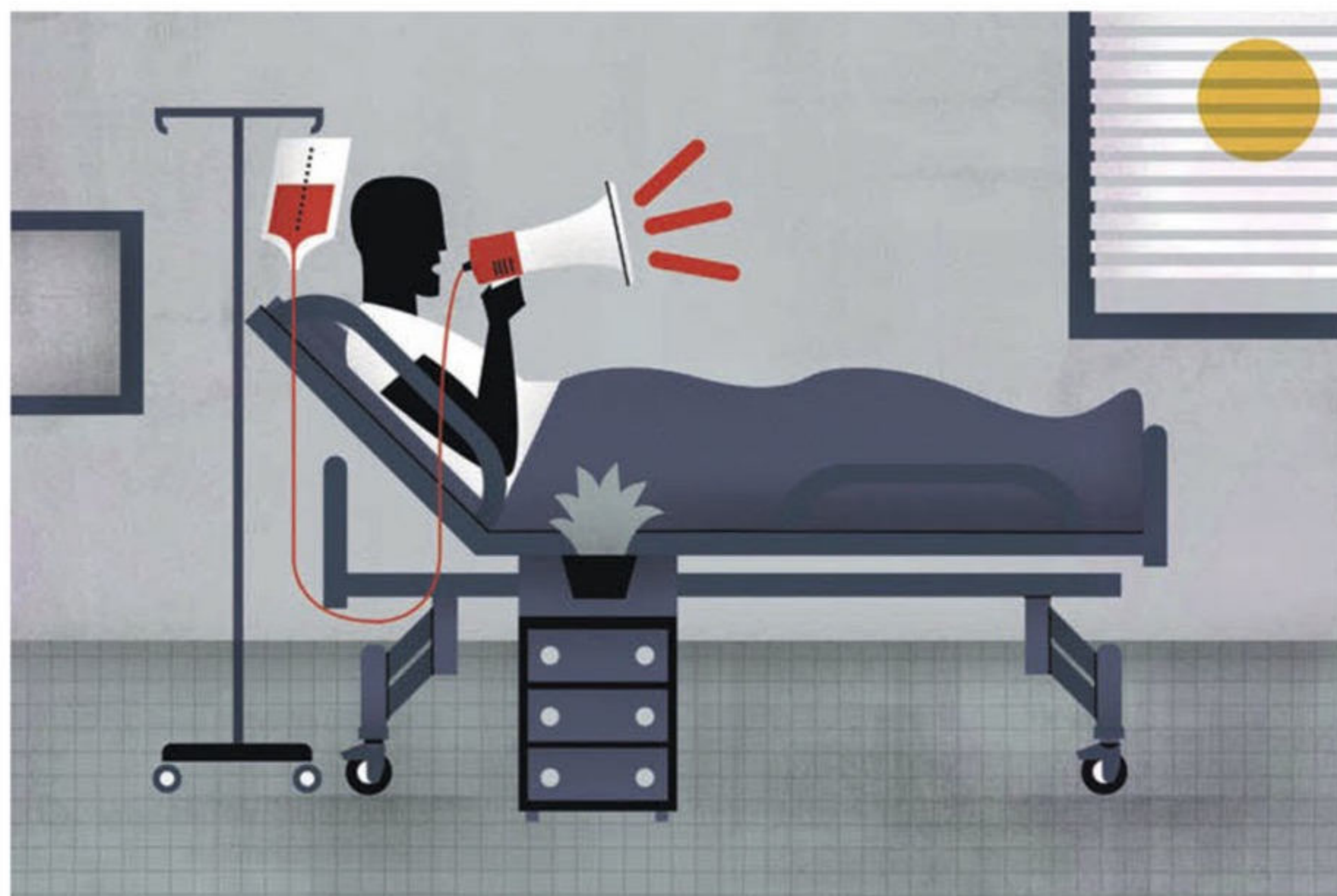
But Sir Iain is also concerned about the relevance of what even responsible

“*Researchers spend millions searching for elusive miracle cures, while patients want research into less glamorous issues like counselling*”

scientists do. Hardly a week goes by without researchers hailing a new 'wonder drug' for some condition or other. Yet whether patients are impressed is another question – and that's one rarely asked, said Sir Iain. When it is, the results aren't always what researchers might want to hear. He cited the example of the bone disease osteoarthritis, for which huge sums have been spent searching for new drugs, while what patients actually want is research into replacement knee joints. It's a similar story in conditions like stroke and asthma, where researchers spend millions searching for elusive miracle cures, while patients want research into less glamorous issues like counselling and the long-term effects of existing drugs.

Sir Iain is now a driving force behind the James Lind Alliance, which is helping to give patients a voice in deciding how the millions spent on medical research are targeted. All very inspiring – and it reminded me of an idea put forward some years back by another troublemaker, the controversial biologist Dr Rupert Sheldrake. He suggested that one per cent of Britain's science budget should be set aside to fund research into questions the public wants answered.

And why not? After all, it's taxpayers who provide the £3 billion annual science budget, and £30 million could fund some decent research. But on what? I'd like to see some large studies of complementary medicine, to finally get to the bottom of these popular but unorthodox treatments. You may have your own suggestions of scientific mysteries in need of some decent research; if so, drop the editor a line and let us know. Who knows, he might persuade someone to set up a study of it. Personally I'd be delighted, as it would mean at least one interesting paper in those research journals.





The Futurist **Stephen Baxter**

Space: archaeology's final frontier



Archaeology has become a very sophisticated discipline on Earth – and we have already begun to apply it on other planets. Specialists such as PJ Capelotti, based at Penn State University and author of *The Human Archaeology Of Space*, are developing space archaeology as an academic discipline.

The first interplanetary archaeologist was Apollo 12 astronaut Pete Conrad, who landed on the Moon in 1969 and retrieved a camera from an unmanned Surveyor spacecraft that had landed 31 months earlier. Now modern craft such as NASA's Lunar Reconnaissance Orbiter, which has been orbiting the Moon since June 2009, have returned images of the Apollo landing sites, including the footprint trails of astronauts like Conrad himself.

We have been sending unmanned craft to Mars since 1962, and relics of many of these missions survive. NASA's Mariner 9 began orbiting Mars in November 1971. Carl Sagan, who worked on the mission, dreamed of retrieving the craft for the Smithsonian Institution. Sadly, time may be running out: Mariner's orbit will probably decay before 2020.

The Soviets attempted the first landings on Mars in 1971. But Mars 2 crashed, while Mars 3 lost telemetry after just 20 seconds of landing. It's not even clear where they are, an objective for future archaeologists. The first American landers were the spectacular Vikings, in July and August 1976. The remains of such craft have already been photographed by the high-

resolution cameras of later orbital probes, but visiting them will tell us about the behaviour of materials and systems over decades in the Martian environment.

And then there are the mysteries. Two-thirds of all missions to Mars have failed, and the most frustrating thing for mission planners is that they often never find out what went wrong. It would be intriguing to learn the fate of lost craft such as the Mars Polar Lander and Britain's Beagle 2.

Elsewhere, the Soviet Union mounted a heroic assault on Venus between 1966 and 1982, achieving 12 landings. Most landers returned little or no data, but the last, Venera 14, survived for 57 minutes in an environment of over 450°C. Future archaeologists may learn much about the resilience of our materials in Venus's harsh conditions, as well as recognising an epic achievement of a now-vanished nation.

Our most distant lander so far is Huygens, which touched down on Saturn's moon Titan in 2005. Soon it will be covered by Titan's slow drizzle of petrochemical rain. Its recovery would be difficult, but may tell us something about Titan's climate history since the landing.

Of course, we may wish to preserve these relics of a heroic age of space exploration in situ. One day there may be parks on the Moon where the footprints of the first astronauts are preserved forever, and perhaps on an inhabited Mars of the very far future, the areas around ancient landers like the Vikings will be saved as samples of primitive Martian wilderness.

MEET THE COLUMNISTS

The Futurist **Stephen Baxter**

A pre-eminent science-fiction writer and regular *Focus* contributor, his books include *The Science Of Avatar* and the popular *Destiny's Children* series.

The Insider **Henry Gee**

A senior editor of the respected science journal *Nature*, Henry is the author of several books, including *The Science Of Middle Earth*.

The Eco-sceptic **Tom Heap**

Tom is an expert on all things green. He presents *Panorama* on BBC One and *Costing The Earth* on Radio 4, which questions accepted truths on green issues.

The Analyst **Robert Matthews**

After studying physics at Oxford University, Robert became a science writer. He is a visiting reader in science at Aston University.

The Medic **Michael Mosley**

After training as a doctor, Michael joined the BBC to become a presenter, writer and producer. He's *The One Show's* science man and presented *The Story Of Science*.



The Eco-sceptic **Tom Heap**

The answer to climate change? It's all in the mind

Let the polar bear shed its tracker and Earth observation satellites burn up in the atmosphere: the cutting-edge of climate science is the human brain.

Noticing that increasing physical proof of man-made global warming is having a dwindling impact on politics and practice – the fact that global CO₂ emissions recently rebounded to hit a record high is a case in point – some climate scientists are switching their talents to working out why facts don't get through our thick skulls.

Chief among them is Prof Chris Rapley who, as Director of the Science Museum, was shaken by the furore that greeted attempts to educate visitors on climate change. Now as Professor of Climate Science at University College London, he has decided to peer inside our heads to find out exactly what's going on.

If past research is anything to go by, 'motivated inference' – forming beliefs based on goals and emotions rather than facts – is likely to be a significant factor. If you distrust 'big government' but like big cars, you might well reject science that supports a carbon tax. There's also the neurophysiological explanation that the subconscious is self-interested and overrides logic.

First impressions from Rapley's research suggest that dissolving denial is such a long-term task we should simply avoid trying to do it. In other words leave the belief, change the behaviour. When you hear a known environmentalist saying we should go green for the sake of British jobs and energy security – while swerving any mention of climate change – you know they are preaching to the *unconverted*.

For Rapley, a physicist who spent many years running the British Antarctic Survey, it's a brave step from the solidity of 'number' science into the murky mental world. But to turn facts from ice cores into action on the ground, you need to drill into the mind.

WHAT DO YOU THINK?

What do scientists need to do to alter attitudes on climate change?
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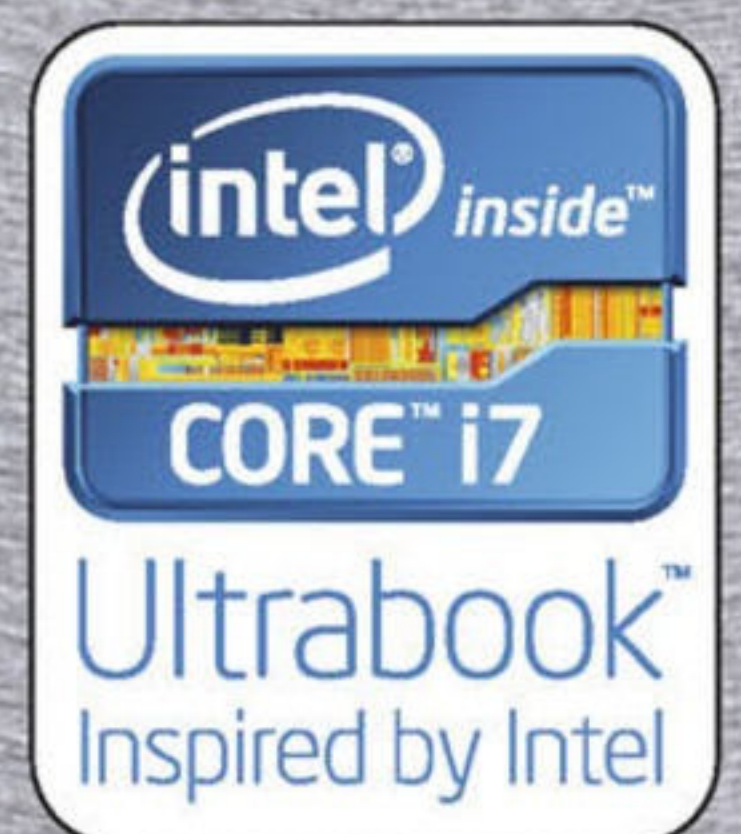
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Climate secrets



I very much enjoyed Bill McGuire's fascinating article 'Climate Change's Nasty Secret' (March, p63), which taught me something completely new. When discussing climate change with my students, I have always maintained that while there are numerous effects that can be attributed to rising temperatures and CO₂ levels, Earth's natural disasters like earthquakes and volcanic eruptions are not part of it. Now, reading Bill's article has caused me to re-evaluate this assertion.

His intriguing suggestion that melting ice caps release pressure on the land beneath, which then transfers that pressure to the ocean floor, puts me in mind of a 'mattress spring effect'. As the occupant of a bed rolls over, some springs 'pop up' while others are compressed as the weight is redistributed... I feel an explanatory graphic coming on!

I have one question. Bill mentions previous occasions in Earth's tectonic history when ice sheets have melted, causing "magnitude 8 earthquakes" and a "tsunami 25m high when it struck the Shetland Isles and 6m high when it flooded Scotland". What sort of geological record is left behind to provide information of this accuracy?

Julian Berkeley, Lake District

Bill McGuire replies: We know about these extraordinary events because of the impressive legacies they left behind. Great fault scarps more than



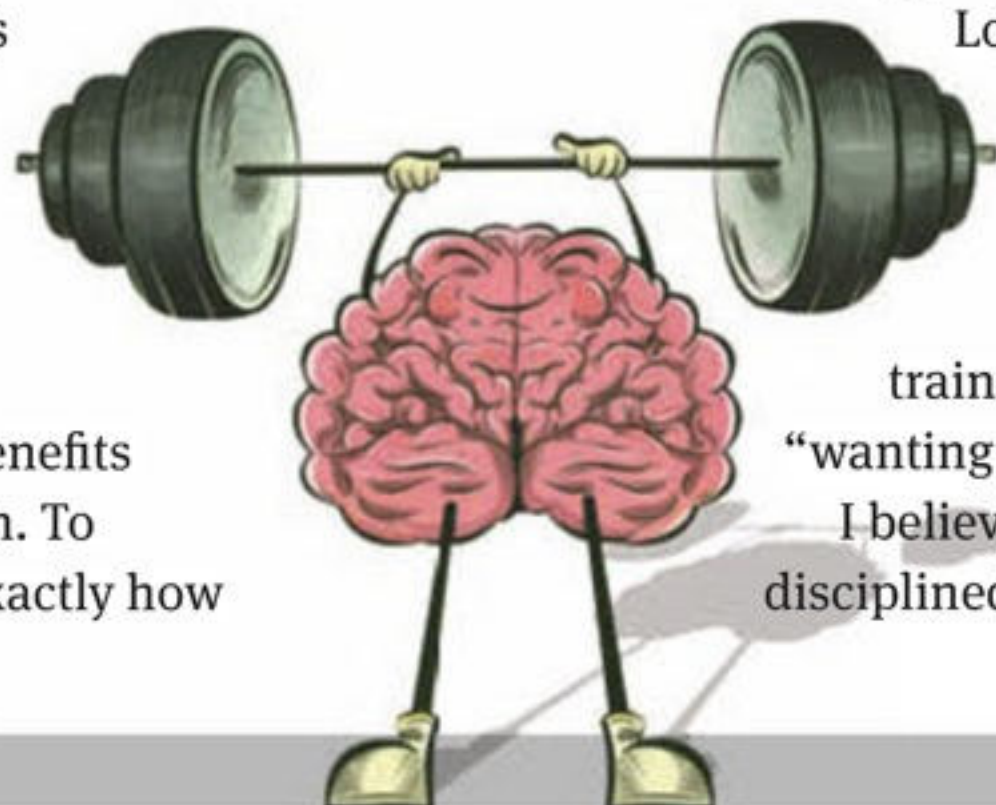
Melting ice sheets can have catastrophic consequences

150km long slash across northern Sweden and Norway, formed when the outburst of massive quakes shook Lapland and tore the crust. Within the peat of the Shetland Isles, a thick layer of marine sand marks the passage of the Storegga tsunami as it penetrated far inshore. Similar deposits are also found on the coast of Norway itself and down Scotland's east side.

Mind over matter



It was a great article on willpower (April, p61)! The idea that you can discipline your mind and improve self-control through various techniques is something that most of us would agree with. However, what's not so obvious is the fact that OD-ing on willpower may not necessarily have all the benefits in the long run. To understand exactly how



much willpower the brain needs to use, a fair amount of experience with it is needed in the first place. From that experience, I can back up a number of the points raised. For instance, it's crucial for me to monitor my exercise – I make a note on each day that I go to the gym, cycle or run.

Looking back at the calendar motivates me further, and I have basically trained myself into "wanting more stars". I believe that being disciplined in one thing

improves your willpower in other walks of life. Health and fitness is important to me, but I never deny myself chips or a big chunk of chocolate cake at a restaurant. What I do have is the willpower never to store it at home. I always know the chocolate cake will be there; I just have to wait for the next occasion! Completely denying yourself the 'good stuff' would be a waste of time and you would OD on willpower, which in turn 'exhausts' your brain and leads to failure. We know that over-exercising at the gym through some crazy New Year's resolution often leads to a slump in February.

When exercising, you need the discipline to think about your goals properly, plan the exercises or have someone to help or motivate you.

Tomasz Schafernaker, London

Wire me up!



Provided the medical science was sound and the procedures properly controlled, I would be happy to allow my brain to have mild electric shock treatment, in order to restore lost memory and problem-solving skills. Incidentally, similar arguments apply to the use of certain drugs. On a wider basis, although humans

WHAT DO YOU THINK?

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Submarine exploration could be left to robots, argues Alan Thomas

are the most intelligent animals, we lack the intelligence necessary to solve the biggest problems, such as controlling large-scale economics, looking after our planet, and living together in harmony. All this would require an ethical dimension as well as high intelligence.

Maybe, in the long term, we can look forward to a better world.

Roger Collison, Holmfirth

Going nuclear



I read April's letter of the month ('Courting

disaster') and gasped in horror. Was this collection of straw-man arguments and ridicule really the finest piece of correspondence to cross your desk that month?

Nuclear power is the sole method of generating energy sufficient to meet the needs of a pre-Kardashev civilisation. Wind, tidal and wave sources are limited by the laws of thermodynamics, solar power is not yet efficient and fossil fuels are dirty and dangerous. The biggest obstacle to clean, plentiful energy in the foreseeable future is the hysterical reaction of a misled public.

Reactor design is not a stagnant field. Small reactors in sealed units that do not require a crew will be on the market before long. These units are designed to cool down if things go wrong, avoiding catastrophic failures. The provider will then arrive and change the reactor, much like a shipping container-sized battery.

The benefits of a distributed power grid would include resilience against disaster and a source of income for the owner (surplus power to be sold back to the grid). No hammer required.

Peter Morgan, Coventry.

Journey to the deep



The article 'The race to explore the deep' left me wondering

how long it will be before the floors of our oceans become like the world's rainforests – exploited and dying fast. That aside, a remotely-controlled submersible could be used far more cheaply and without endangering life – but as always, great strides in exploration are only considered truly newsworthy when there are people involved.

NASA's Mars rovers have achieved amazing results, but

without the human-in-danger aspect, their endeavours have hardly been front-page news. I find it disheartening to think that there must be a risk of loss of life before there is heightened interest.

As for Richard Branson's submersible having aeroplane-like 'wings', do people really still believe that the curvature of a wing's upper surface is what produces lift? Anyone proficient in folding paper planes will know that lift comes from the angle of attack deflecting airflow downwards, resulting in Newton's equal and opposite reaction.

Otherwise, if the wing's curvature were what keeps planes aloft, then how could a plane fly upside down?

Alan Thomas, Shepperton

I think you'll find...

In your April 2012 issue, in answer to the question "Why do we say 'Ow!'?", Luis Villazon wrote that Germans say "Ach!" when experiencing pain ('Q&A', p89).

I've lived in Germany for over 30 years and I've never heard that one. They say "Au!" or "Aua!" when stubbing their toes. "Ach" means "Oh!" or "Oh well" or "Come off it!", depending on the intonation and how loud you say it.

Joan Robinson, Mannheim, Germany

On page 46 of Issue 237 (and again on page 114), you state that a pound of fat contains more energy than a pound of dynamite. However, if $E=mc^2$ then surely a pound of anything has exactly the same energy as a pound of anything else?

Phil Douglas, Auckland, New Zealand

In one sense you're correct. However, the article referred to the amount of energy that could be extracted, which in the case of food is calories. For fat, that's more than you get from dynamite when it explodes. –Ed

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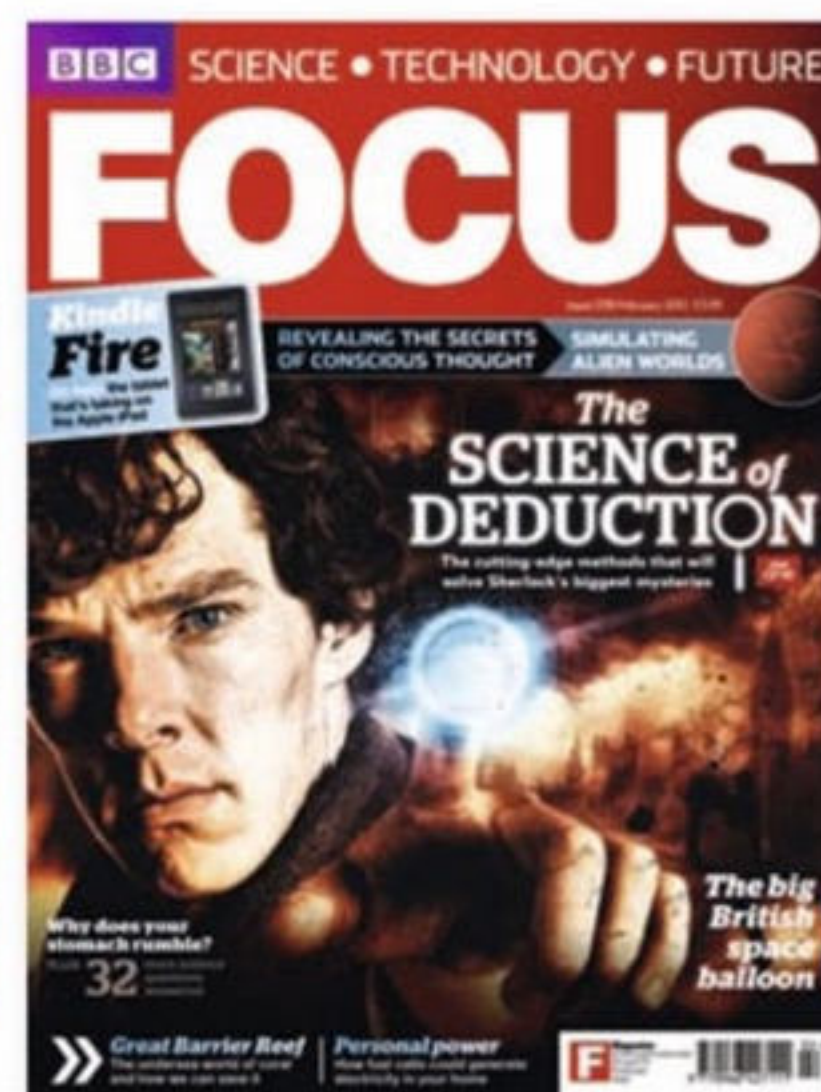
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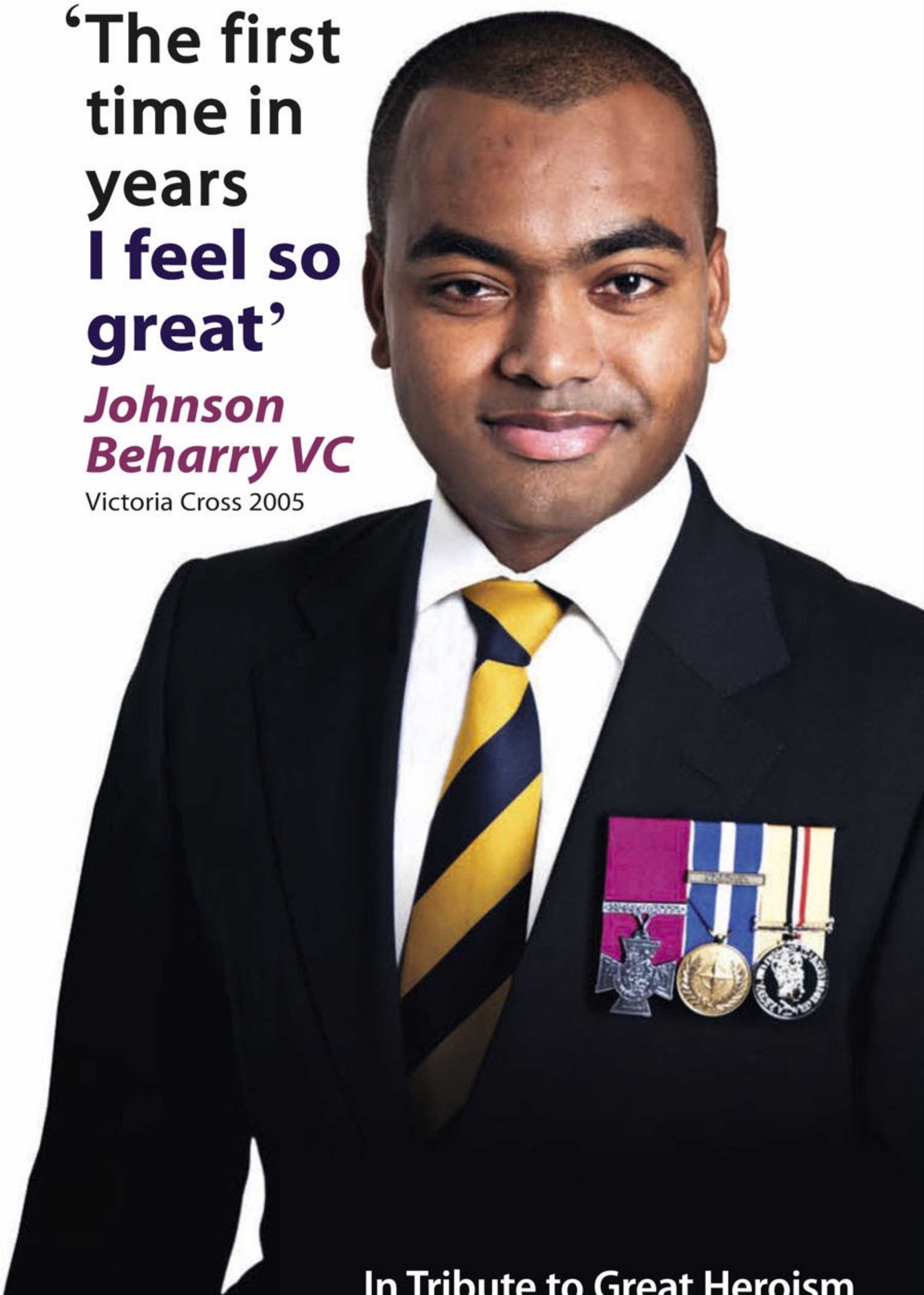
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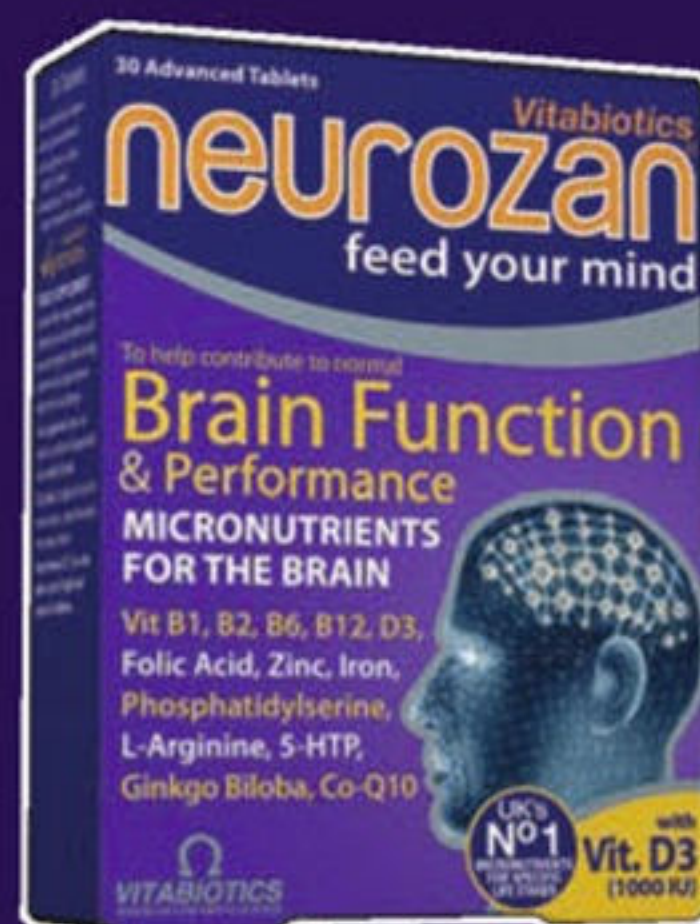

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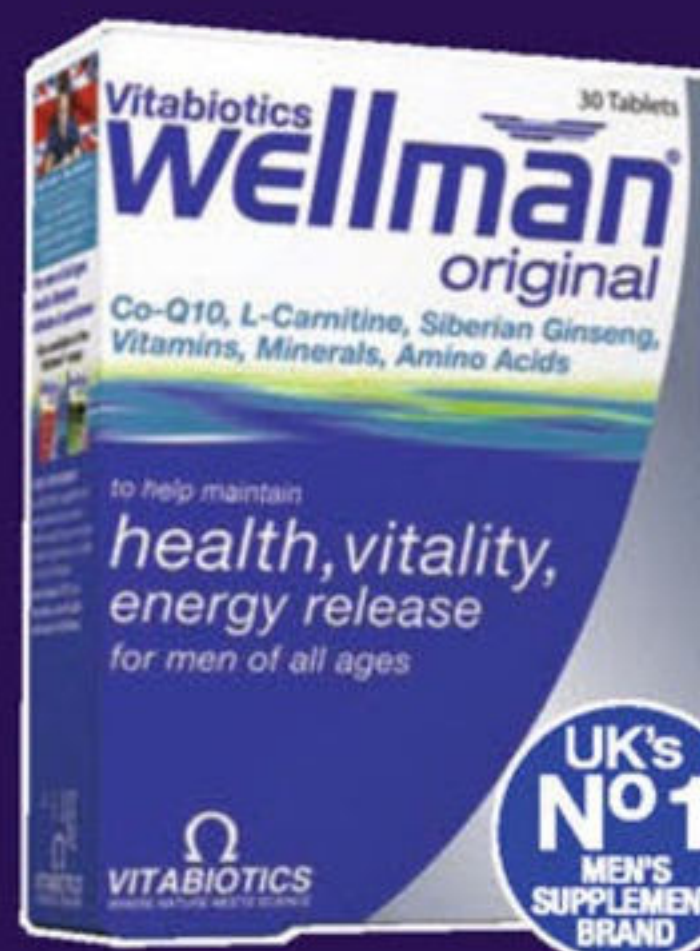
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SPECIAL REPORT

THE ORIGIN OF LIFE

Every living thing on Earth evolved from a single ancestor. But where did it come from, and how did it form? JV Chamary looks back in time



ILLUSTRATION BY PATRICK BOYER



How did life begin? Undoubtedly the biggest question in biology, it's also one of the hardest to answer – and the most controversial. Scientists debate every step in the path to the first living organisms, and revealing the molecules and mechanisms that drive life will almost guarantee a Nobel Prize.

Part of the problem with studying the genesis of biology is that it leads to another tough question: what is 'life'? And there are over a dozen definitions. NASA's exobiology programme, for example, adopted a definition of life as "a self-sustaining chemical system capable of Darwinian evolution". So one way to identify life's common characteristics is to remember that living things aren't really 'things' at all – life is a process, which is driven by chemical reactions, or metabolism.

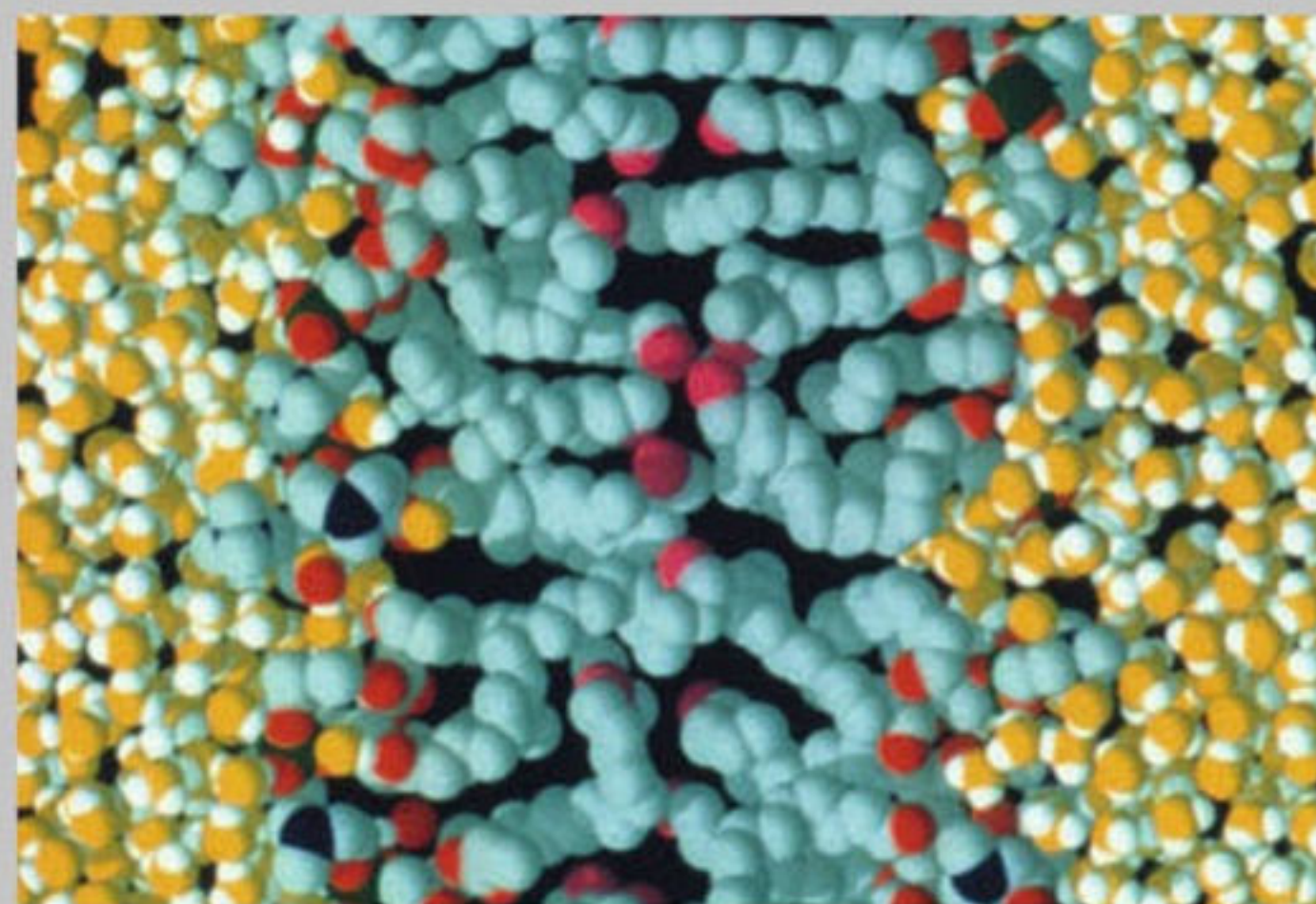
But while we don't have all the answers to how life originated, recent research is offering exciting new clues. Last year, scientists revealed the world's oldest fossils, found in

3.4 billion-year-old sandstone from Strelley Pool, Western Australia, one of the first known stretches of beach. This rock contains microscopic structures that look like cells. They're surrounded by a chemical fingerprint of biological activity: isotopes of carbon in proportions that indicate conversion from inorganic CO₂ into organic molecules produced by living cells.

"We came across remarkably well-preserved things in little windows between the sand grains, which seem to have avoided all the usual crushing and cooking," says Prof Martin Brasier, a palaeobiologist at Oxford University. "These are cell-like structures: we find biological-type morphology; the chemistry is consistent with biological metabolic pathways."

The chemistry of the rock also suggests that these primitive microbes generated energy through chemical reactions that use sulphur, similar to sulphur bacteria found today. This means that these ancient microbes were a relatively sophisticated form of life and unlikely to represent the very first living organisms.

BEFORE

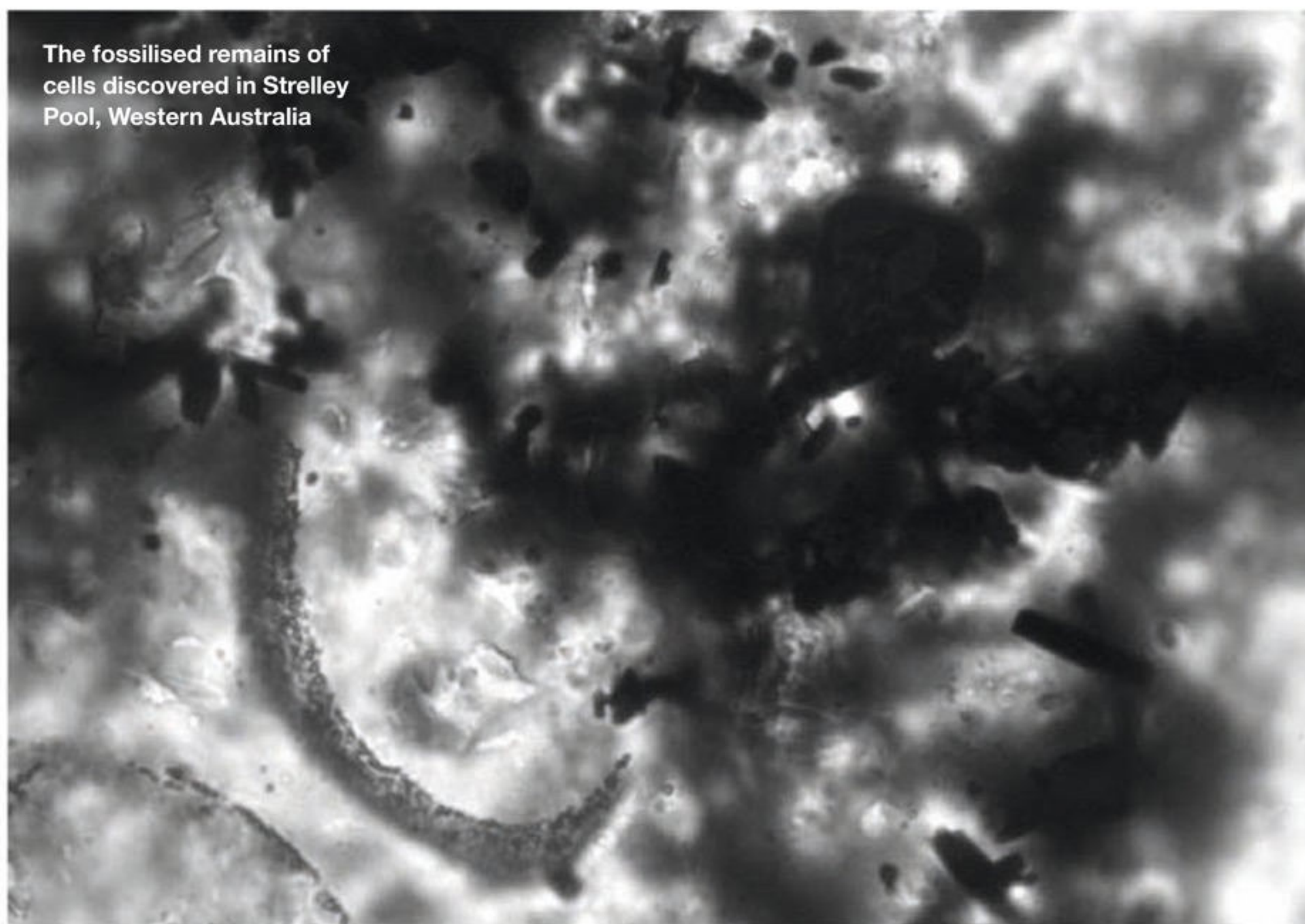


LIPIDS

Biological membranes (cross-section pictured) are made up of phospholipid molecules that self-assemble into a spherical structure. "Virtually all lipids are products of life," says Prof David Deamer of the University of California, Santa Cruz. "But a cell emerging on the early Earth would need a source of membranes that are not biological."

In 1985, Deamer extracted a fatty acid (a lipid) from a carbon-rich meteorite. Like phospholipids, the fatty acid was able to self-assemble into a sphere. Pre-life could have used this as a cell before it gained the ability to produce its own phospholipid membrane. This doesn't mean meteorites delivered membranes to Earth, but that reactions that occur in asteroids – which generate meteorites – provide a guide to how lipids could have once been synthesised.

The fossilised remains of cells discovered in Strelley Pool, Western Australia



So when did life begin? It's unlikely that the first organisms appeared earlier than four billion years ago, 500 million years after Earth's formation. Back then, our planet was a watery world with land in the form of arcs of islands, but no true continents. Our Sun was only 70 per cent as bright as it is today, with volcanic activity bringing temperatures up to clement conditions, at around 25 to 60°C.

Early Earth

Compared to today, the Moon was closer, generating stronger tides, and the Earth was spinning faster, meaning shorter days lasting eight to 10 hours. The surface was also regularly pummelled by rocky debris left over from the early Solar System during an event called the Late Heavy Bombardment, when meteorites 10 times larger than the one that killed the dinosaurs were not uncommon.

BIOLOGY

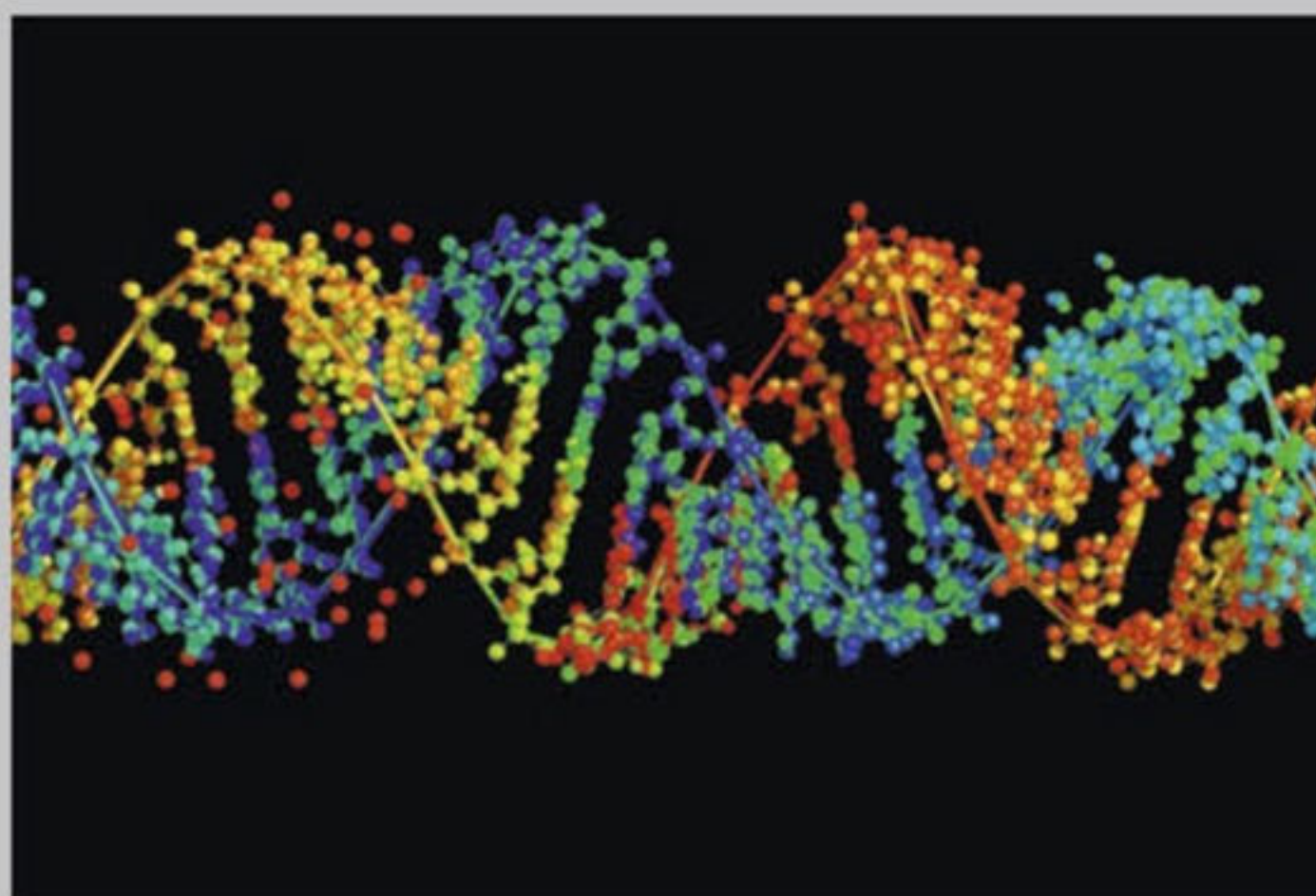
Investigating the chemical origin of life's building blocks



AMINO ACIDS

Before life could make amino acids (pictured), the building blocks of proteins, most were brought to Earth by comets and meteorites. To find out how amino acids might be synthesised in space, Prof Uwe Meierhenrich, a chemist at the University of Nice, is studying an artificial comet.

"Astrophysicists assume that comets are formed by the condensation of molecules on small dust particles in interstellar clouds," Meierhenrich explains. To create the artificial comet, water and molecules like CO₂ and ammonia were subjected to electromagnetic radiation from UV light. Meierhenrich found that the condensation process had created complex molecules: 26 different amino acids. To help unravel the mysteries of life's origins, his team is part of the Rosetta space mission, which aims to land on a comet in 2015.



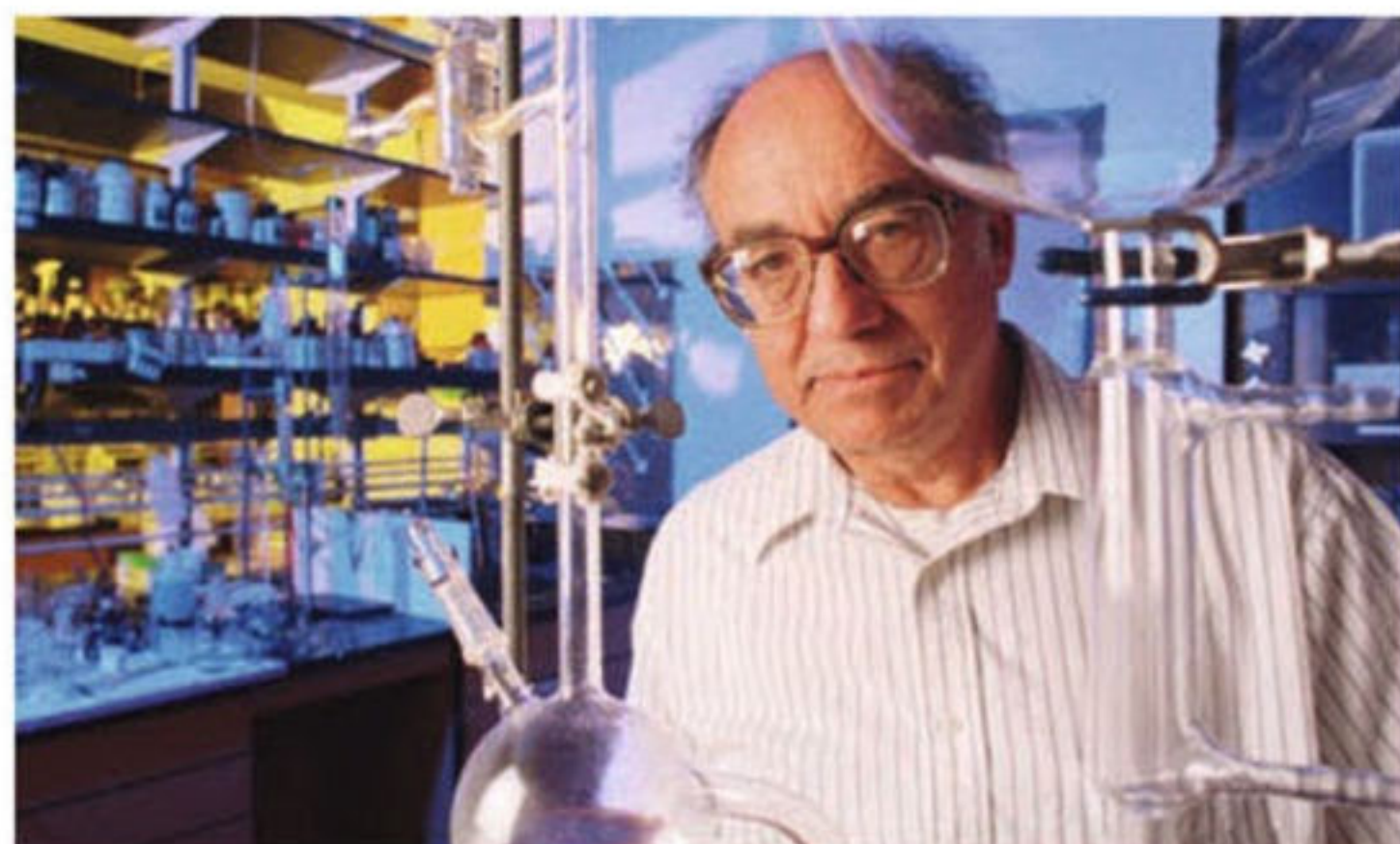
NUCLEOTIDES

In 2009, chemists Matthew Powner and John Sutherland of Manchester University managed to synthesise nucleotides – the 'letters' in DNA and RNA – from ingredients that were probably present on Earth four billion years ago. "The compounds we used could potentially be made by geochemical and atmospheric processes," says Dr Powner, now at University College London. "The term we use is 'prebiotically plausible'."

Powner created numerous nucleotides. When he exposed them to UV light, the nucleotides that aren't used by life today were destroyed, leaving two out of the four nucleotides that are used in RNA. This suggests that sunlight on the early Earth could have driven a process like natural selection to synthesise the 'fittest', most stable nucleotides.

Ending 3.8 billion years ago, this Hadean eon – named after the Ancient Greek underworld – sounds like hell on Earth, but it was heaven for the first microbes. Meteorites would have delivered important metals and some of life's building blocks to the surface, for instance, while volcanic power and sunlight provided free energy. So although early Earth would seem

Stanley Miller with the apparatus of the Miller-Urey experiment



hostile to us, it would have been a lively place in terms of generating life.

Cloaked by greenhouse gases, the atmosphere had no oxygen – a waste product of photosynthesis generated by plants and algae, which didn't exist at that time. Instead, the early atmosphere would have contained methane, carbon dioxide, sulphur dioxide, hydrogen sulphide, and plenty of water vapour. "All these things sound toxic to us, but most are perfect fuels for microbial life," says Brasier. "It was a microbial paradise."

We may never discover physical remains of early life preserved in the fossil record further back in time than the Australian micro-fossils. "Beyond 3.5 billion years ago, the evidence is wholly mineral or chemical, perhaps because these older rocks are too cooked to preserve the remains of cells," Brasier explains. "All of life is cellular – that is why fossilised cells

provide a fundamental benchmark for the beginnings of life."

So in order to reconstruct the events that came before the first cells, some scientists are taking a different approach: they're simulating how life might have once evolved by creating its ingredients in the laboratory. This approach was inspired by an idea from the 1920s, which proposed that the first organisms emerged from a 'primordial soup' of organic molecules.

A seminal test of this soup theory was carried out in 1952 by chemists Stanley Miller and Harold Urey. Using a sealed glass apparatus, they passed an electric spark (to simulate lightning) through a mixture of gases thought to have been present in Earth's primitive atmosphere: methane, ammonia, hydrogen and steam. The water that condensed in the artificial 'ocean' contained amino acids – the building blocks of proteins necessary for life. ►



The early Earth was a microbial paradise, with an atmosphere loaded with greenhouse gases and abundant energy from volcanoes

► Scientists who study the chemistry that preceded the first cells (see 'Before Biology', p34) emphasise that life didn't appear in a single event. "The origin of life is not a Big Bang," says Dr Philipp Holliger of the MRC Laboratory of Molecular Biology in Cambridge. "There isn't a divine spark where things come alive – it's more a transition. There would have been a grey zone where things became more and more life-like."

So if cooking up the precursors to life in a primordial soup needs a slow simmer, what are the ingredients? All living things are made up of DNA, RNA, proteins and lipids – four molecules that each play a crucial role in cells. Lipids, for instance, make

up the membrane – the barrier that separates a cell from the external environment, enabling it to regulate its internal metabolic reactions. But while life's recipe always includes these four ingredients, this may not always have been the case.

RNA world

The paradox is this: in modern cells, proteins provide structural support and act as enzymes – catalysts that enable chemical reactions – while the genes in DNA encode the information for producing the proteins. So it's a classic chicken-or-egg conundrum: which came first, DNA or proteins?

The answer, it seems, is neither. They were preceded by DNA's big

NEED TO KNOW RNA

A molecule similar to DNA, made from nucleotide building blocks. Its sequence of nucleotides can encode genetic information and folded RNA sometimes acts as enzymes.

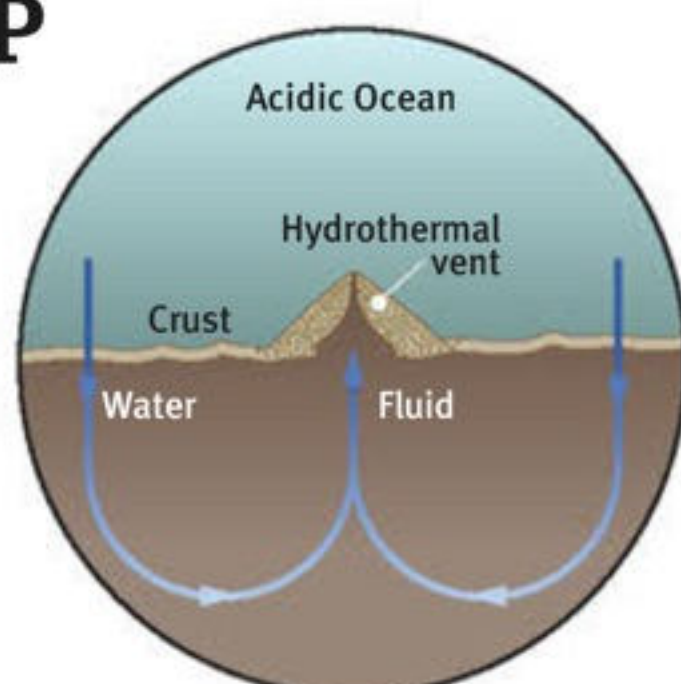
brother: RNA. Although they're both formed from nucleotides, the four 'letters' that make up DNA and RNA sequences, the two molecules have different personalities. While RNA is a reactive molecule consisting of a single strand of nucleotides, DNA's characteristic double-helix structure makes it chemically stable, and therefore a more reliable molecule to use as a store for genetic information. Like proteins, RNA strands can also fold into three-dimensional structures that bring molecules together to help catalyse reactions.

In principle then, RNA could perform the functions of DNA and proteins, acting both as information carrier and catalyst. If the reactions

TIMELINE

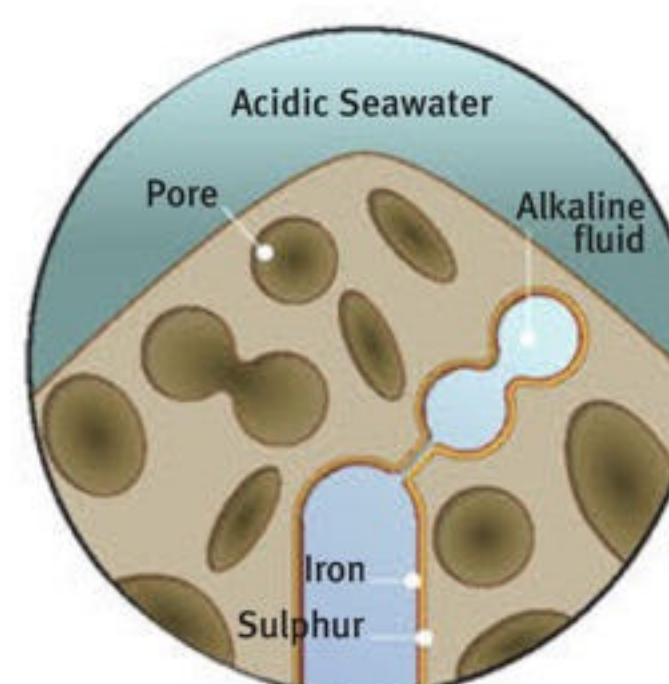
FROM SOUP TO CELLS

The complex chemistry that shows how life might have evolved at a hydrothermal vent



1. PRIMORDIAL SOUP

Water seeps down through the Earth's crust and reacts with minerals to produce a hot fluid rich in hydrogen and sulphur. This alkaline fluid rises up through the sea floor (a vent) and reacts with iron in the ocean, forming iron-sulphur bubbles that precipitate as a hydrothermal mound.



2. METABOLISM

Organic molecules are synthesised from CO_2 (from seawater) and hydrogen (in the vent fluid), the reactions catalysed on the iron-sulphur surface of pores in the mound. The difference in acidity between acidic seawater and alkaline vent creates a proton gradient between pores.

included the ability to string together nucleotides to create a copy of itself, the molecule would have possessed life's defining properties: the ability to replicate and inherit information. In other words, to reproduce.

Most biologists believe that RNA could have been the 'first replicator' and that the primordial Earth was once an 'RNA world', dominated by these precursors to life. The best evidence to support this comes from ribosomes, the cell's protein-making factories. Most of the reactions in cells are catalysed by proteins acting as enzymes, but the enzyme at the heart of the ribosome is actually a 'ribozyme' – an enzyme made of RNA. As the ribosome is used by all life, it's probably an ancient remnant from the RNA world.

The self-replicating molecule from the RNA world has been lost in the mists of time, however. "The best we can do is build a molecular doppelgänger in the lab, and try to study its properties to help us understand what went on four billion years ago," says Holliger. "Self-replication, together with heredity, would provide a transition from the world of chemistry to the world of biology," he explains. So far, he has created a 200-letter-long RNA enzyme that can read and write short stretches of RNA, including its own sequence of nucleotides. The aim is to get this RNA enzyme to copy its entire sequence.

Mistakes in the copying process, known as mutations, could actually cause an RNA to become better (faster or more accurate) at replication. And with a limited supply of resources

in the environment, in the form of the nucleotide building blocks, you would effectively end up with a form of evolution by natural selection. It would be 'chemical selection' driven by survival of the most efficient catalysts.

The first cell

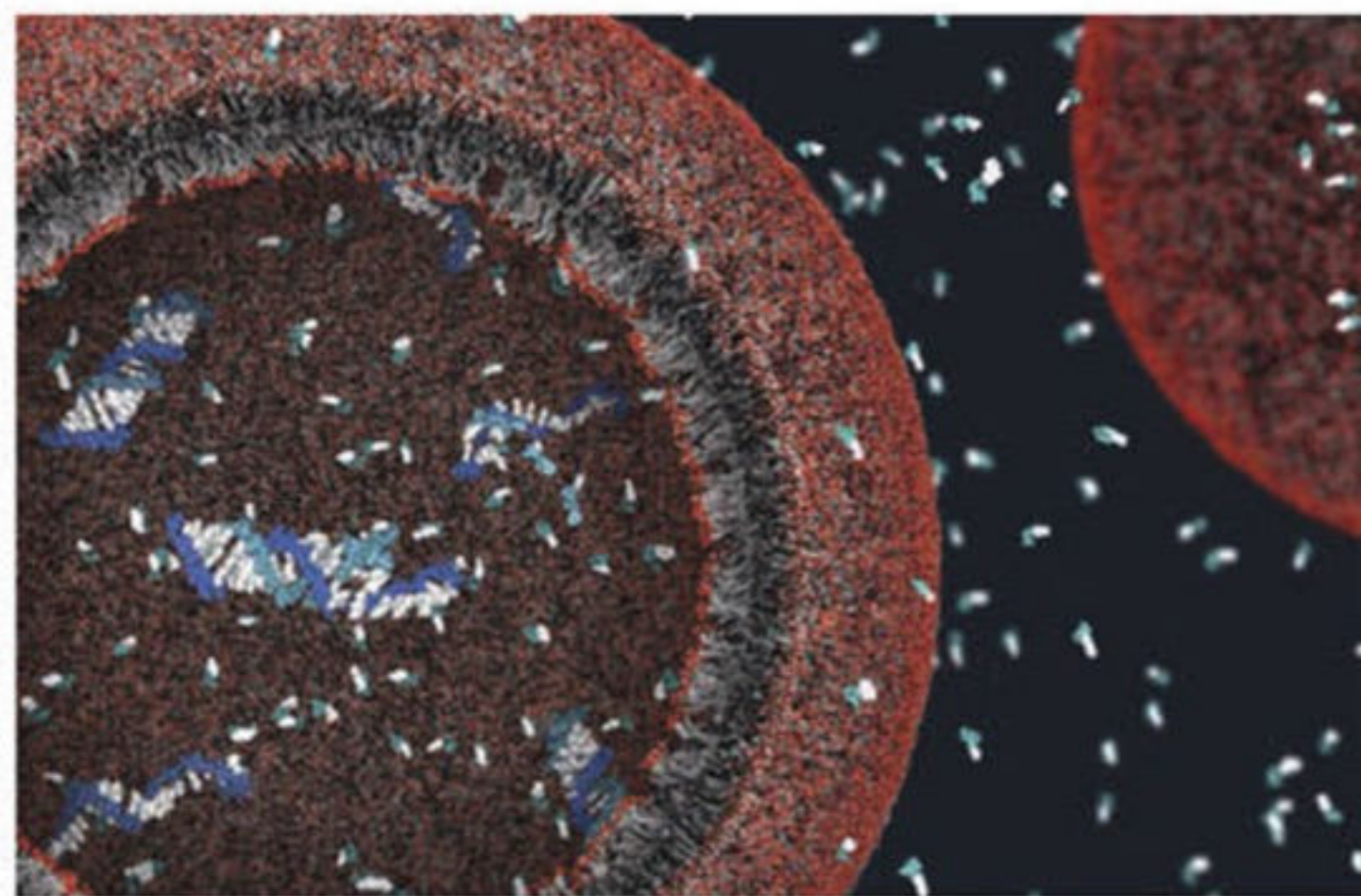
The next step in reconstructing life is to create a cell. Membranes are made of lipids, molecules with a water-loving head and a fat-loving tail. These form a double layer (bilayer) of lipids in which the fat-loving parts of the molecules face each other to form the oily filling in a water-loving sandwich.

Like oil droplets in water, the chemical groups that prefer water or fat clump together, spontaneously self-assembling to form a 'vesicle', a sphere with water on the outside and inside. And if the contents of this lipid bubble contains RNA, you've effectively created a primitive cell, or 'proto-cell'.

Studying the behaviour of RNA enclosed within these proto-cells has led to some interesting insights into

"The origin of life is not a Big Bang. There would have been a grey zone where things became more and more life-like."

A computer model of a proto-cell, revealing a lipid membrane surrounding DNA

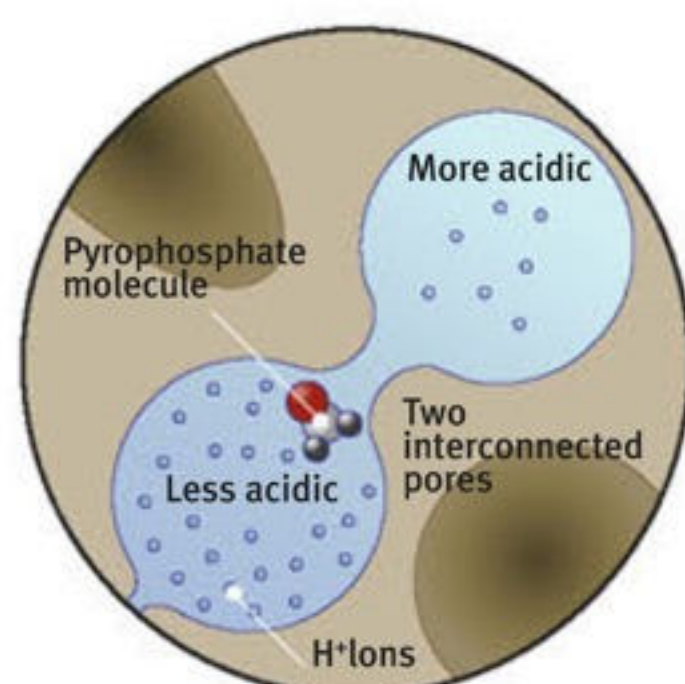


the precursors to life. While working with proto-cell pioneer Jack Szostak, biophysicist Irene Chen of Harvard University discovered that proto-cells swell as RNA replicates.

Membranes are 'leaky' when it comes to small molecules such as nucleotides. But once they're inside, nucleotides are strung together into long RNA strands that are too big to leave. And because RNA molecules are negatively charged, small positively-charged ions are dragged into the cell through electrostatic attraction. Water then follows the ions through osmosis, causing the proto-cell to swell.

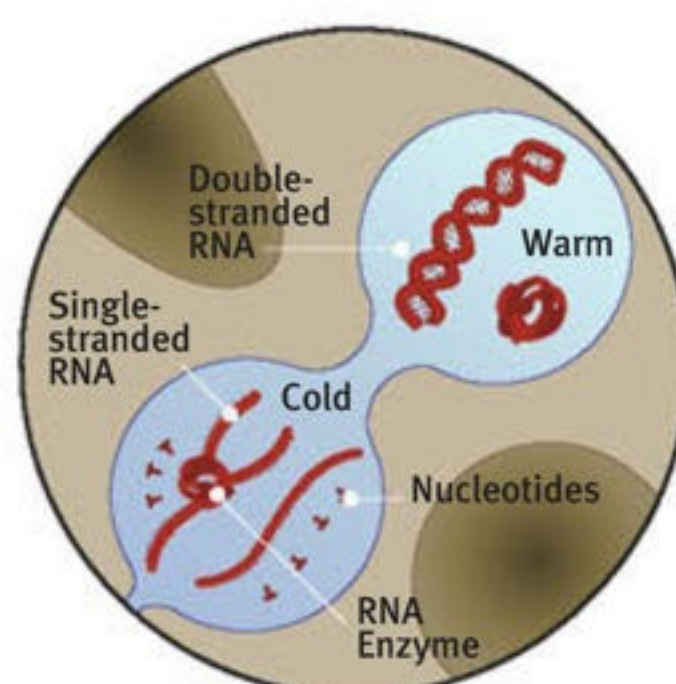
"We found that the RNA could translate its growth directly into the growth of the cell as a whole," Chen explains. "It doesn't require enzymes or anything else to be added to the system, it's just a consequence of the physical and chemical properties." Cells that exploit the available resources to grow faster would then be able to out-compete others – the beginnings of natural selection.

But some scientists doubt that reproducing life in the lab will ever tell the story of how it all began. "Even if we made an experiment today where we put chemicals on one side and got newly synthesised life out the other side, it still wouldn't prove that we arose that way – we'd just have a narrative that would make it more plausible," says Prof Bill Martin, an evolutionary biologist at the University of Düsseldorf in Germany, who adds that the idea of life emerging in a primordial soup filled with organic



3. ENERGY EXCHANGE

Molecules emerge that act as an 'energy currency'. Today, all cells use ATP, but early life used a simpler molecule like pyrophosphate. These molecules capture energy from the electrochemical proton gradient and release it to synthesise complex molecules from life's building blocks.



4. RNA WORLD

RNA and other molecules get concentrated in pores through hydrothermal currents. In the warmer pores, double-stranded RNA molecules separate to create two templates for making more RNA by adding nucleotides. In colder pores, RNA folds into enzymes that copy the RNA molecule itself.

► molecules is outdated. “Organic soup has been around as a concept for 80 years, before anybody had a clue as to how cells actually harness energy.”

The major point of contention among researchers centres on the source of the soup’s ingredients. “There’s an assumption that you simply fill the soup with whatever you want,” says biochemist Dr Nick Lane of University College London. “The problem is that there’s no evidence there ever was a soup like that.”

Energy exchange

Whereas many ‘RNA world’ supporters think RNA arose first and evolved the ability to consume organic molecules already present in the soup,

others believe that cells had to first become capable of producing organic molecules and generating energy through metabolism. For proponents of this ‘metabolism first’ origin of life, such as Lane and Martin, organisms could only evolve if the environment contained a system for generating the energy required to drive the chemical reactions of metabolism.

Today, in all cells that contain a nucleus and use oxygen, energy is generated by mitochondria. These structures, the powerhouses of the cell, generate energy through the movement of charged atoms (ions) across their membrane, creating an electrochemical gradient between the inside and outside.

NEED TO KNOW

Proton

In chemistry, a proton is a positively charged hydrogen ion (H^+). In biology, the flow of protons helps create an electrochemical gradient that can be used to generate energy.

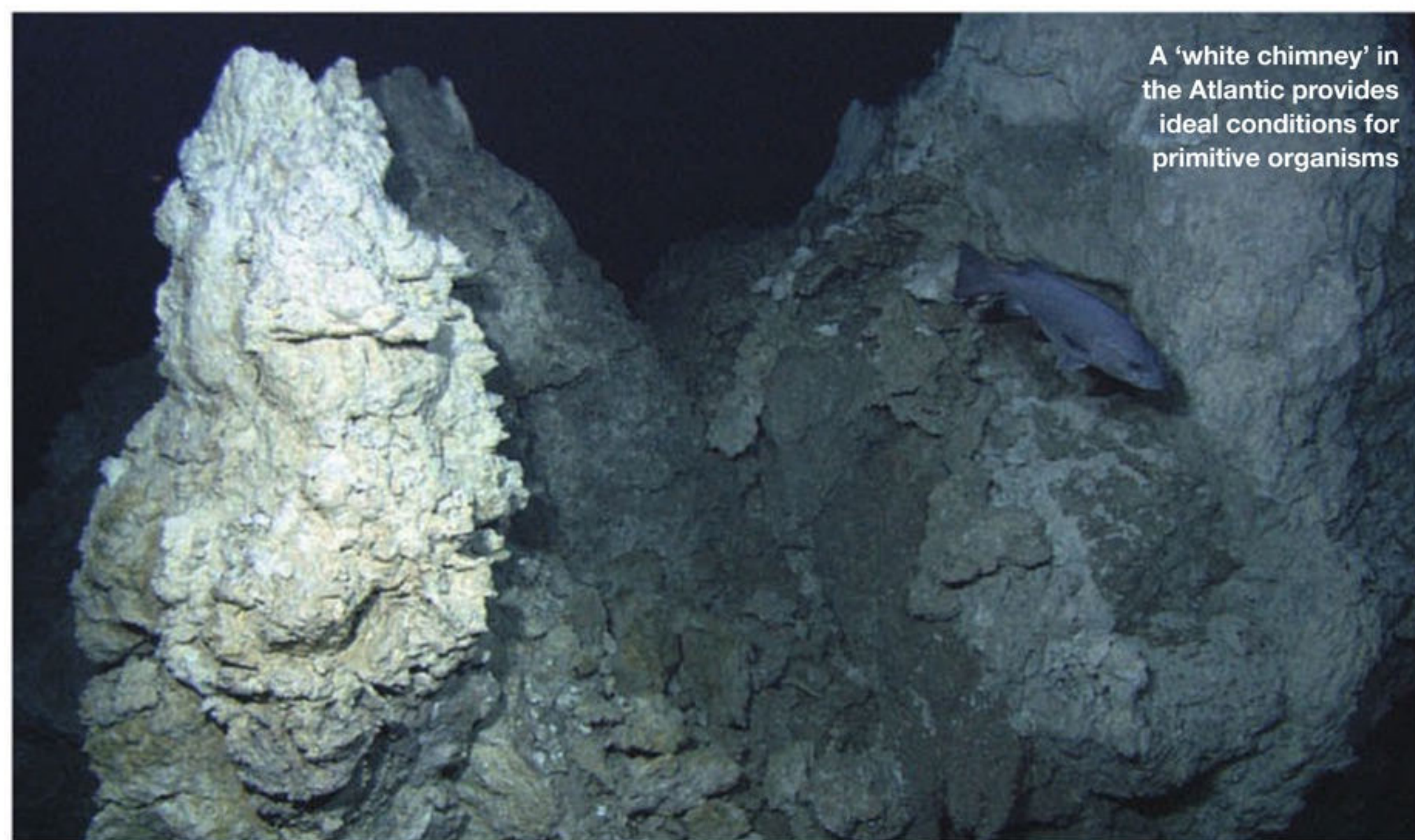
Imagine a hydroelectric dam: the pressure created from having more water on one side generates power as water flows through a turbine. Something similar happens in mitochondria, but with protons (hydrogen ions) replacing water: protons flow down a gradient in concentration from high to low inside a mitochondrion. The protons pass through a molecular ‘turbine’ called ATP synthase, generating power.

Meanwhile, the ATP synthase ‘turbine’ uses the energy released from the flow of protons to manufacture ATP molecules, the energy currency of the cell. ATP is used to pay for the chemical reactions needed for life; an adult human will make their own body weight in ATP every day, recycling each molecule over 1,000 times.

And it’s proton gradients that ‘metabolism first’ scientists believe generated the energy necessary to sustain early life. The question is, what produced these gradients before oxygen, membranes and ATP synthase? To answer *how* life began from energy, you also need to know *where* these gradients already exist.

Cradle of life

Did life begin on land or at sea? In 1871, Darwin said he hoped it began in a “warm little pond”, and this remains a big debate. In February 2012, physicist Armen Mulkidjanian suggested that, based on the composition of ions in modern cells, life might have evolved near geothermal pools in Kamchatka

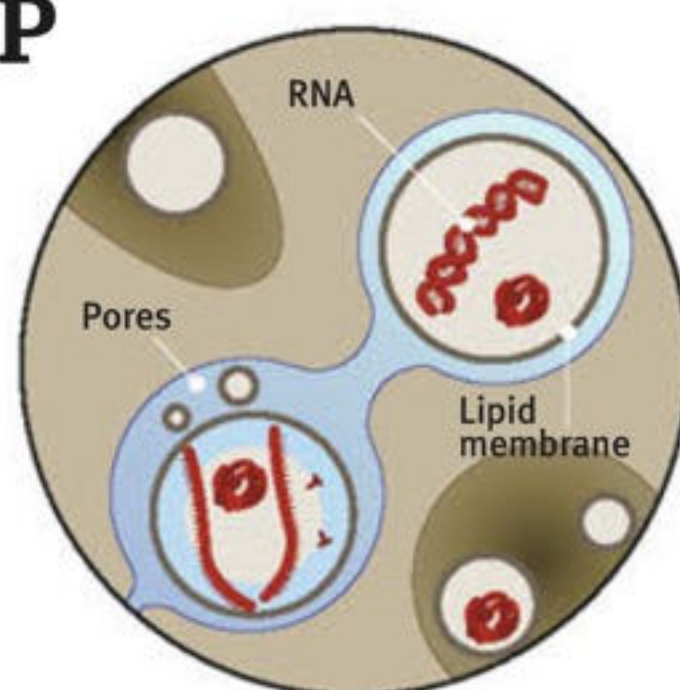


A ‘white chimney’ in the Atlantic provides ideal conditions for primitive organisms

TIMELINE (CONTINUED)

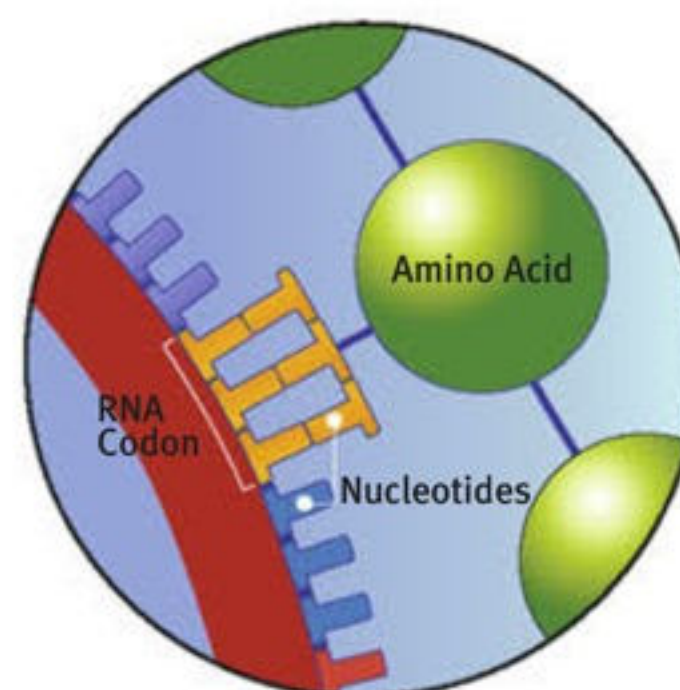
FROM SOUP TO CELLS

The complex chemistry that shows how life might have evolved at a hydrothermal vent



5. PROTO-CELLS

Membranes (made from lipids) assemble into cell-like bubbles, which enclose other molecules to form proto-cells. Self-replication of RNA forces cells to divide. Mistakes in copying RNA (mutations) create a variety of cells that compete for resources – the start of natural selection.



6. THE GENETIC CODE

Amino acids bond to several RNA letters to create words (codons). The full vocabulary of different words forms the genetic code, which allows the four-letter alphabet of RNA to be translated into the language of proteins. Instructions for making proteins from amino acids is encoded in genes.

(near Siberia), similar to those in Yellowstone National Park in the US. Highly controversial, critics point out that the early Earth didn't have much land – reducing the potential space on which life could form – and that rain could wash away or dilute the contents of the pools. Other proposals include beach-sized rafts of pumice stone and underwater 'mud volcanoes' now exposed above sea level in Greenland – see 'Where did life begin?', right.

The ocean is another option, as the depths could have protected early life from the damaging effects of UV rays. Until recently, the leading contender was hydrothermal vents called 'black smokers', formed at fissures in the sea floor that release superheated water. But these are relatively short-lived, too hot for life (400°C) and too acidic.

The leading candidate for the cradle of life is alkaline hydrothermal vents, like those at Lost City, a region of stone towers along a volcanic fault in the mid-Atlantic. Minerals from alkaline vents precipitate as mounds, but can grow to form intricate, white chimney-like structures. What's special about these vents is that heated water emerges at under 100°C – cool enough for life – and they're thought to last 100,000 years, long enough to give life a good chance to get going.

Most importantly though, the alkaline interior of hydrothermal mounds maintains a natural proton gradient that early life might have exploited to generate energy. "Think of a hydrothermal mound as an energy and materials capturing device, like ►

WHERE DID LIFE BEGIN?

Alternatives to the theory that life started in ocean vents...

PUMICE RAFTS

Perhaps best known for its use as an exfoliant in your bathroom, volcanic pumice (the light-coloured stone pictured) may be a contender. Once it's erupted from a volcano, pumice floats on water in 'rafts' before being swept onto beaches by the tide. According to Oxford's Prof Martin Brasier and David Wacey of the University of Western Australia, the porous pumice would play host to organic materials and metals while being baked by ultraviolet light from the Sun and possibly hit by lightning, kicking off chemical reactions.

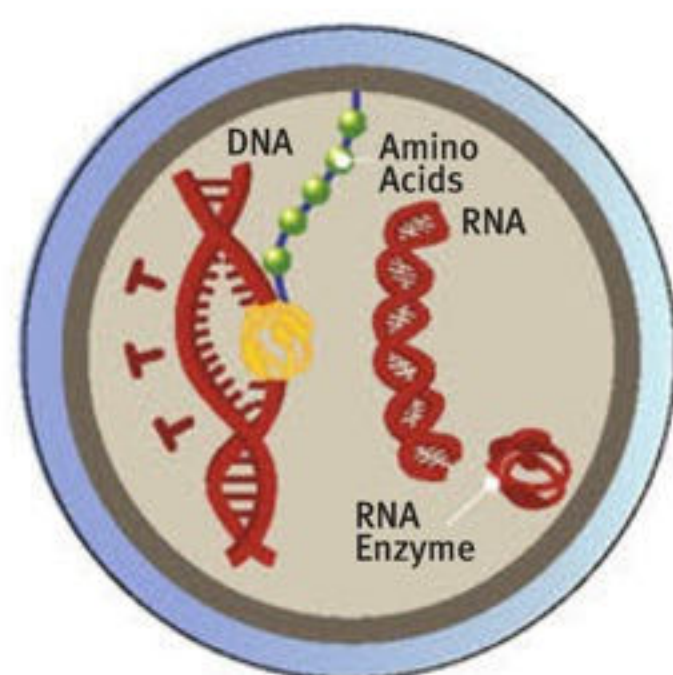


MUD VOLCANOES

The rocks of Isua (pictured) in southwest Greenland are some of the world's oldest, at 3.8 billion years old – a time when there was very little land covering the Earth's surface. By studying serpentinites from Isua, scientists from the Laboratoire de Géologie de Lyon: Terre, Planètes et Environnement, believe that the ingredients for organic molecules to form, and be stable, would have been present in ancient deep-sea mud volcanoes. Serpentinite mineral forms when seawater comes into contact with igneous rock.

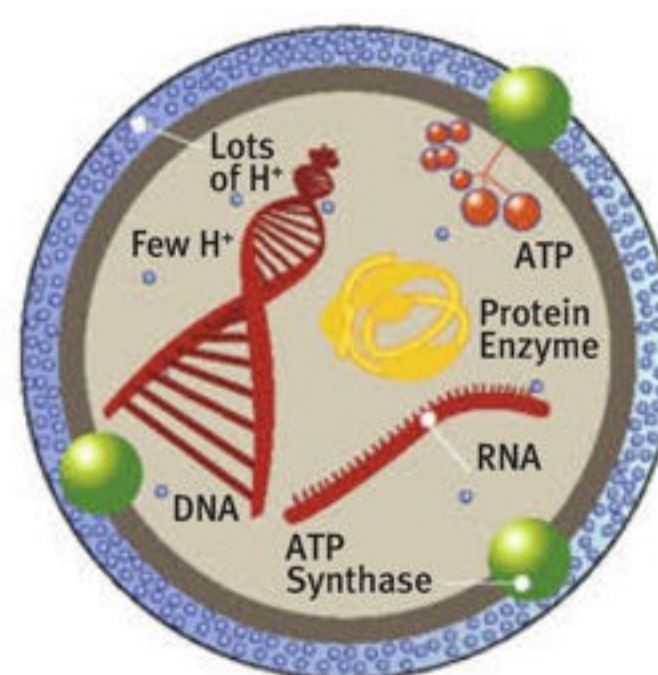
GEO THERMAL POOLS

The controversial idea that life began in an inland, geothermal pond was inspired by the fact that the composition of cells today differs greatly from that of seawater. According to Armen Mulkidjanian of the University of Osnabruck, cells are rich in ions that are found in places such as geysers, mud pots and openings in the Earth's crust called fumeroles. There's no chance of finding any evidence for the theory, as these primordial ponds would have been highly acidic, although it could be studied in the lab.



7. DNA AND PROTEINS

Being more stable than RNA, DNA takes over the role of storing genetic information. Proteins prove to be better enzymes than RNA and their versatility enables them to catalyse a variety of metabolic reactions. The protein ATP synthase allows proto-cells to capture more energy.



8. CELLS

The evolution of LUCA, the Last Universal Common Ancestor of all life on Earth. Proteins that pump ions out of the cell allow the organism to generate its own electrochemical gradient without needing the difference in acidity at the hydrothermal vent. These primitive microbes are then able to leave the vent.

► a factory that puts the components together on site, rather than just sloshing around in some incredibly dilute soup,” says geochemist Dr Michael Russell of NASA’s Jet Propulsion Laboratory in California, a leading proponent of the theory that life began at alkaline vents.

The proton gradient is driven by the difference in acidity between the seawater and the inside of the vent. Inside the vent is alkaline, while the seawater in the early oceans would have been slightly acidic. A geological process in the Earth’s crust (serpentinisation) delivers a constant flow of hydrogen, as proton ions, into the vent. This maintains the gradient, with protons flowing toward the region of lower concentration: the acidic seawater.

Hydrogen and minerals are pushed through a network of pores in the hydrothermal mound by currents, which helps concentrate molecules in the same place (see Timeline starting on page 36). It’s inside these micro-compartments where life may have begun. The mineral walls between pores act like a membrane, generating a gradient in proton concentrations between adjacent pores.

“You start off with some kind of chemistry happening, but you first need compartments to contain anything that you make,” says Russell.

Power source

The mound walls don’t have the ATP synthase to capture the energy released from the flow of protons. Instead, in the early oceans, the walls would have been made from iron-sulphide, creating a catalytic surface for exchanging electrons between molecules. This enabled hydrogen from the vent to react with CO₂ dissolved in the water, producing organic molecules. In other words, the beginnings of metabolism. “I’m happy with the RNA world, but it’s something that comes in later,” says Russell.

In the ‘metabolism first’ scenario, lipid bubbles would then have formed inside the pores of a hydrothermal



The first organism could have looked like a methanogen, a simple microbe with an ancient metabolism

“The free-living cell is to me the definition of something that is genuinely alive.”

mound and enclosed RNA molecules. Pores are about 10 times larger than a typical microbe, so this would allow space to form the first cells. Later still, DNA would have evolved from RNA, while proteins proved to be better enzymes than RNA. Proteins that then evolved to actively pump ions across the membrane would allow cells to maintain their own gradients for generating energy and enable them to leave the confines of the pores.

“The free-living cell is to me something that can replicate and harvest energy from the environment using chemical reactions that are specified by its genes,” says Bill Martin. But what did the first cells look like? There is no evidence from the ‘RNA world’ because early RNA-based life would have been erased from history. But if metabolism came first, then scientists could gain insights from any ancient metabolic processes that are still being used to synthesise organic molecules.

According to Martin, if the fundamental chemistry worked four billion years ago, there’s no reason why it would have changed. “Early life was very similar to microbes

that we can still observe today.” The most primitive kind of metabolism, says Martin, is one currently used by simple microbes called methanogens, which make methane, and acetogens, producing acetate. So the most ancient organism might have looked like these.

Scientists agree that life had a single origin because the genetic code is shared by every organism. But the order of the evolutionary steps to the first cell will always be controversial. “In evolutionary biology, it’s always about bridging the gaps,” says Martin. “The gap between us and chimpanzees is small. Back to fish, then down to sponges and simple animals, we can sort of imagine that. But the transition from carbon dioxide, water and rocks on the early Earth to living things is very difficult. We know it happens – so the question is not if, just how.” ■

Dr JV Chamary is a biologist and features editor of Focus

FIND OUT MORE

<http://bbc.in/LifeEarth>
BBC Nature – History of life on Earth

Life Ascending: The Ten Great Inventions Of Evolution by Nick Lane (Profile, 2009)



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Ocean in motion

A new NASA animation reveals how currents circulate, and their possible impact on climate change. **James Lloyd** investigates...

This striking image of the North Atlantic ocean is much more than just a pretty picture. It not only shows circulation patterns in detail, but the methods used to create the animation will soon enable scientists to make more accurate predictions about climate change.

The picture you see is a still frame from an animation created by NASA's Scientific Visualization Studio. The white lines in the image show the surface currents, while the blue shading in the ocean indicates the depth of the seafloor below – the darker areas represent deeper waters. The Gulf Stream is clearly visible as a

streak of white that curls around the tip of Florida before working its way up the east coast of the USA.

The Vincent van Gogh-like swirls are features known as eddies – looping currents, typically 10 to 100km in diameter, that can persist for months. These are formed when meanders in the current trap water that's either warmer or cooler than the water around it. This water can completely separate from the main current, forming a circulation pattern similar to the weather systems that are seen in the atmosphere.

This animation was created using data from the ECCO2 (Estimating the Circulation and Climate of the

Ocean, Phase II) project. ECCO2 uses a state-of-the-art numerical model that combines observations from a variety of sources, such as satellites and ocean instruments, at a high enough resolution to show smaller features such as eddies.

“Surprisingly, eddies in the oceans are much smaller than their atmospheric counterparts,” says Patrick Heimbach, an oceanographer at the Massachusetts Institute of Technology (MIT) who is involved with the ECCO2 project. “Therefore, ocean models require much higher resolutions to resolve oceanic weather. Computer simulations which resolve eddies have only become possible in

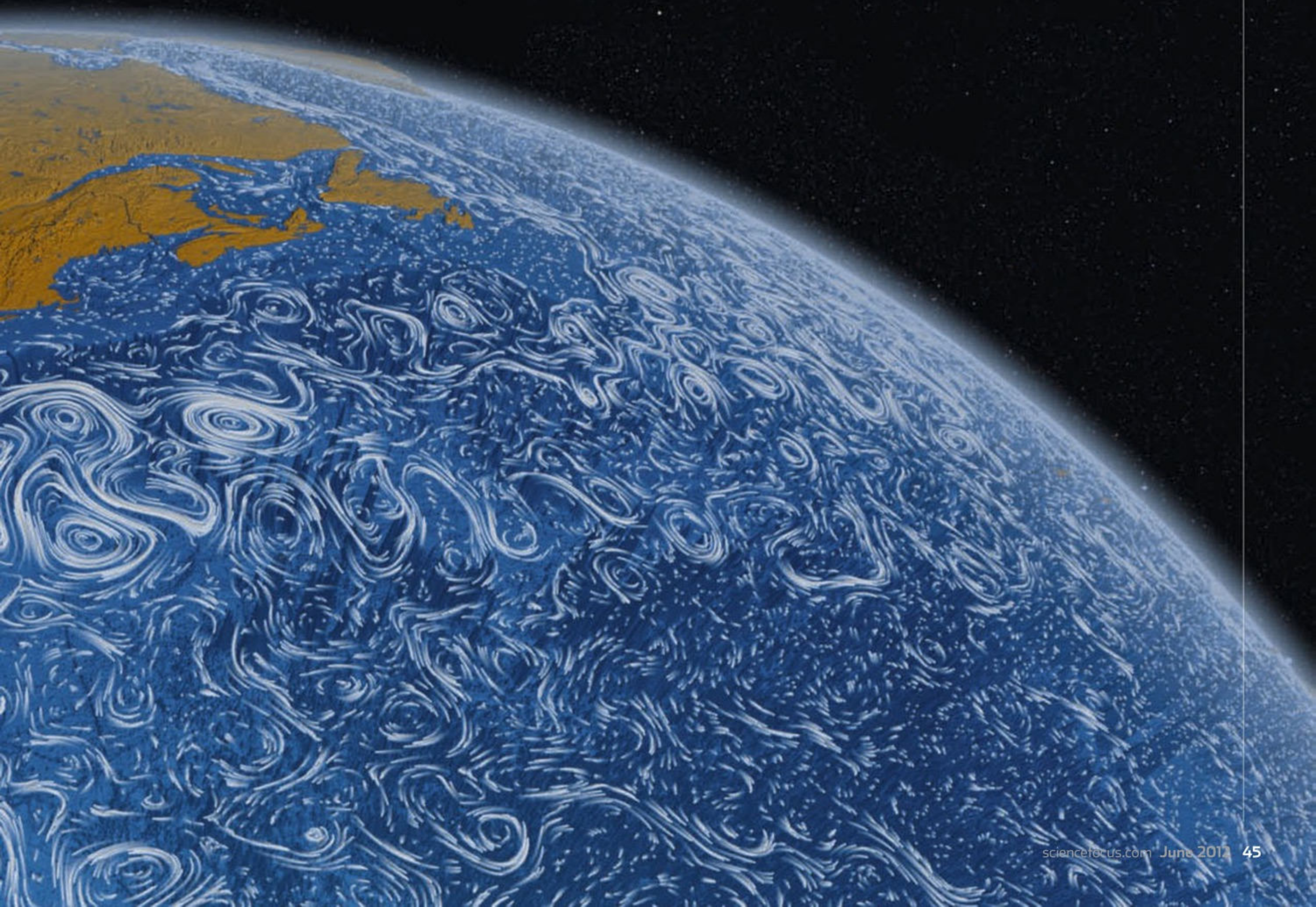
“The van Gogh-like swirls are eddies – looping currents that can persist for months”



recent years, with the advent of high performance supercomputers.”

Eddies are important because they play a key role in moving heat and carbon around the oceans. Research has shown that eddies in the Southern Ocean around Antarctica transport heat polewards; this heat can ultimately be released into the atmosphere, affecting large-scale wind patterns. A better understanding of these processes will therefore help researchers to predict the evolution of the oceans, and our planet's climate, over the coming decades.

The full animation for June 2005 to December 2007 can be viewed here: <http://bit.ly/GJvBMp>



REACH FOR THE STARS





Physicist James Benford describes how the interstellar travel of science-fiction films could one day become a reality

ILLUSTRATIONS BY THOMAS PRINGLE

Why go to the stars? It's a question that's bound to be asked whenever space travel is discussed. One reason might be that our planet's resources are running out – another simply because they're there. We're curious apes, and our interest in interstellar travel features prominently in science-fiction. The forthcoming film *Prometheus*, for instance, is a prequel to *Alien* about an expedition to another world.

To reach the stars, we will have to overcome major obstacles: scientific, social and economic. NASA and DARPA, the military R&D agency, have so far awarded a grant of \$500,000 for the '100 Year Starship' project, a plan to achieve interstellar travel within a century. Growing interest led to a key event last October: the 100 Year Starship Symposium,

attended by the likes of astronomer Jill Tarter and science-fiction writer Stephen Baxter. The aim was to identify problems and offer potential solutions.

The scope is sobering. If you made a scale model of the distance between Earth and the Moon inside a 20m-long meeting room, the nearest star (Alpha Centauri) would be as far away as the real Moon is from Earth. In thousands of years, humans have progressed from strolling at 4km/h to returning from the Moon aboard the Apollo spacecraft at 40,000km/h. But reaching nearby stars in, say decades, would require a velocity jump of another factor of 10,000 – close to the speed of light. We don't just need to get faster – we need to get faster more quickly. Yet despite all the challenges, travel to a distant planet *could* one day be possible. Here's how... ►

STEP 1 BUILD A STARSHIP

Today's rockets only go twice the speed at which gases leave the exhaust nozzle – far too slow for interstellar travel. Starships will need powerful new forms of propulsion

Nuclear rockets

Thrust can only be applied so long as there's fuel onboard, and speed depends exponentially on the mass of fuel. Going three times the exhaust speed would require fuel 20 times the mass of the rest of the rocket (the 'dry weight'). Chemical combustion of hydrogen and oxygen is simply too slow.

Nuclear thermal rockets – in which hydrogen flows through a fission reaction core – would open up the Solar System to large spacecraft which could harvest resources from places such as gas giants, where hydrogen is a major atmospheric component. Nuclear thermal rockets – researched since the Cold War in Russia and the US – are our best hope of reaching high thrust any time soon.

Interstellar travel would require the nuclear reaction that powers the Sun: fusion. In 1978,

a British starship concept called Daedalus suggested using 'inertial fusion' to drive the rocket. Lasers would crush a pellet of hydrogen isotopes from all sides, compressing the material into a tiny volume. Pressures rise enough for the hydrogen nuclei to fuse, releasing energy, and hot mass thrusts out of a nozzle. But while that would get us to nearby stars, reaching them would still take centuries – and first we must achieve fusion here on Earth, which has so far proved elusive.

In the longer term, we could develop matter-antimatter rockets. When antimatter and ordinary matter react, they annihilate one another and generate 300 times the energy of fusion reactions. The problem is that we don't yet have the technology to make much antimatter.

Warp drives

Star Trek uses 'warp drives' to get around the Galaxy quickly. But is faster-than-light (FTL) travel even possible? According to Einstein's General Theory of Relativity, FTL is possible if you have negative mass. With negative mass, you can distort the shape of space-time to allow rapid transit between distant points.

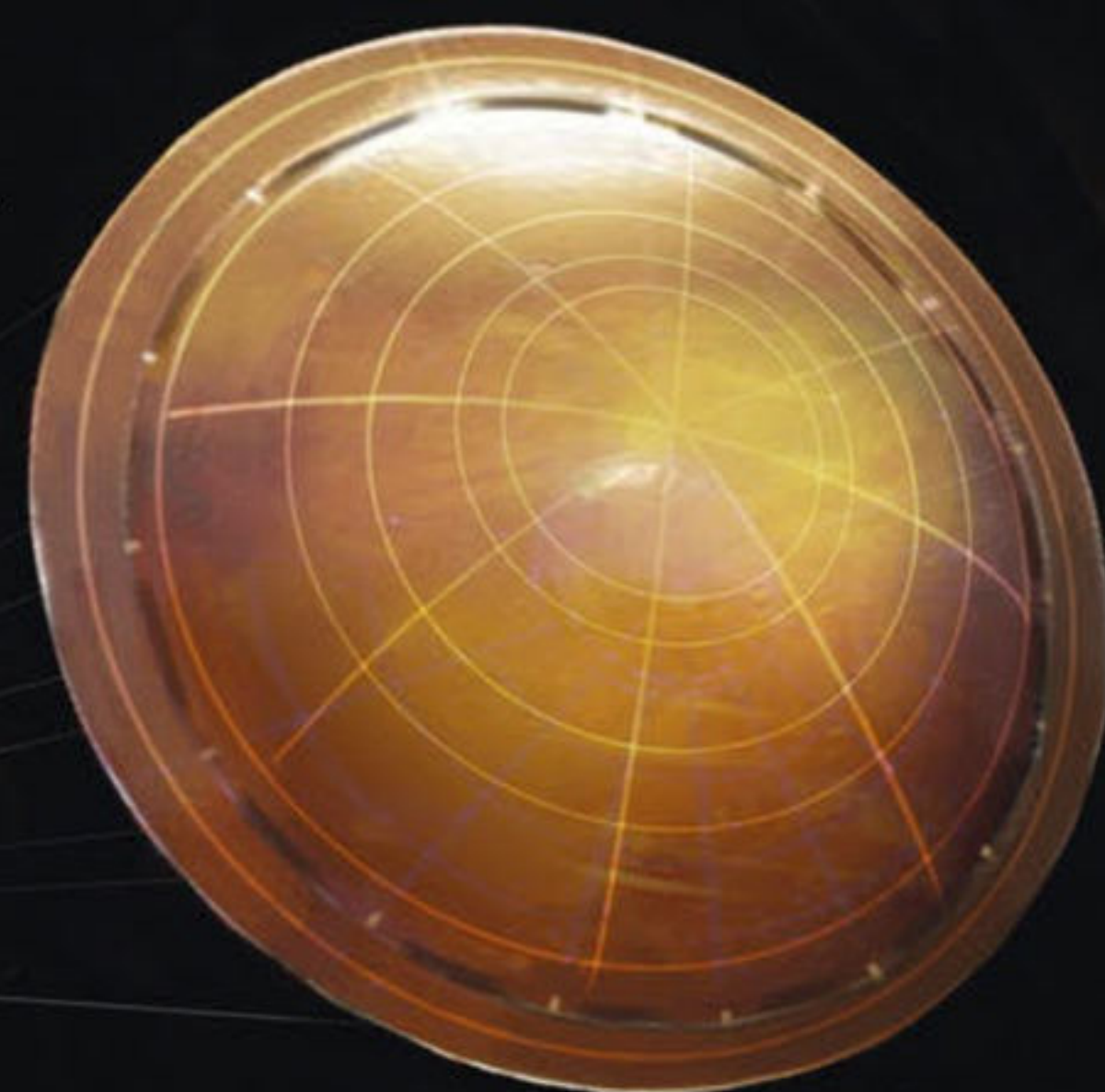
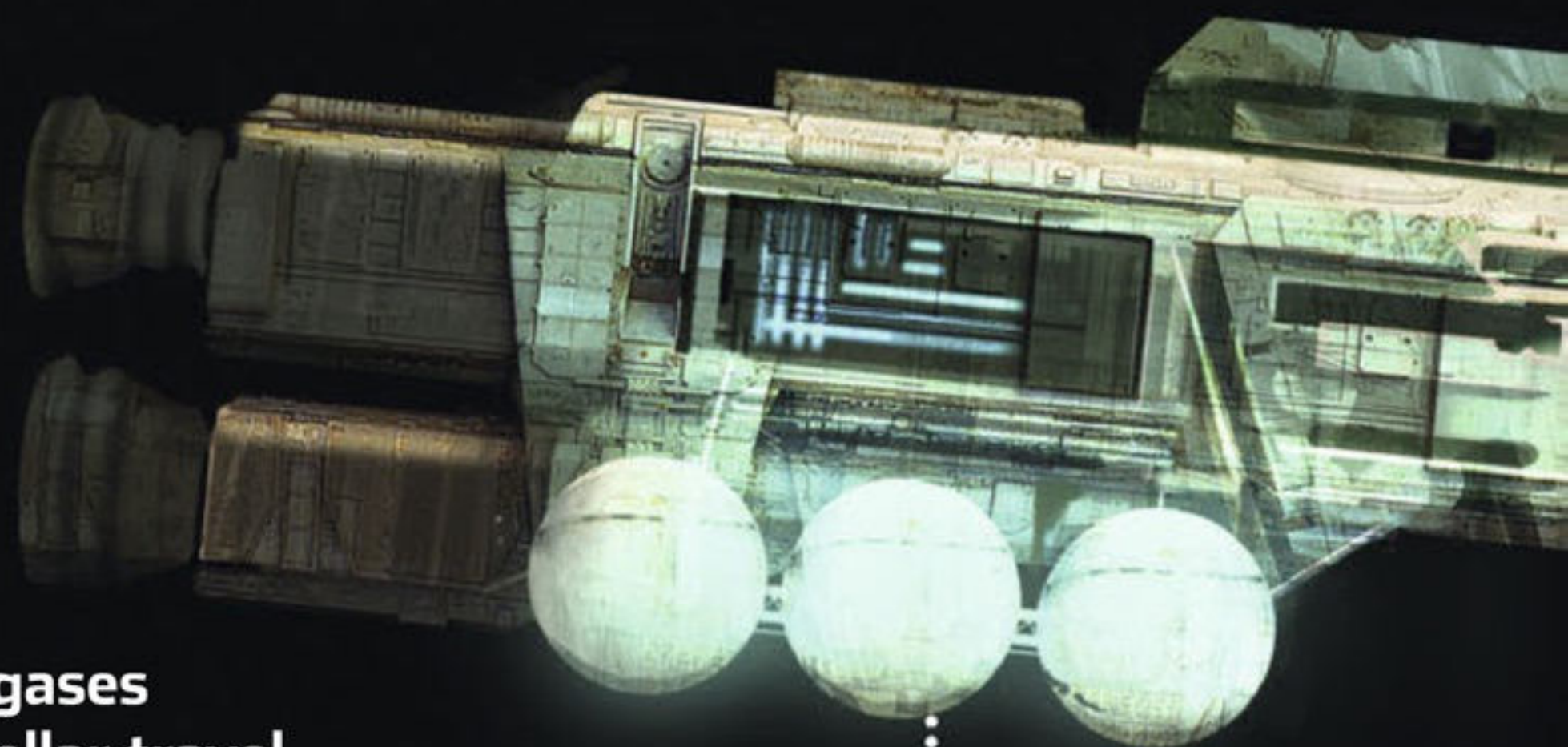
Something with negative mass would behave extremely strangely: it would 'fall up' here on Earth. While it's never been seen, quantum mechanics does allow it to exist. The theoretical physics jury is still out as to whether it could be used for interstellar travel, as you'd need to warp space-time with an incredible amount of energy, far more than could be harnessed from a star.

If you could somehow capture enough energy you could distort a region of space-time, creating a 'warp bubble', as proposed by physicist Miguel Alcubierre. The bubble would be just large enough

to hold a starship. Space-time ahead of the bubble would contract and behind it would expand, driving the ship onwards. But where does the energy come from and how is it generated?

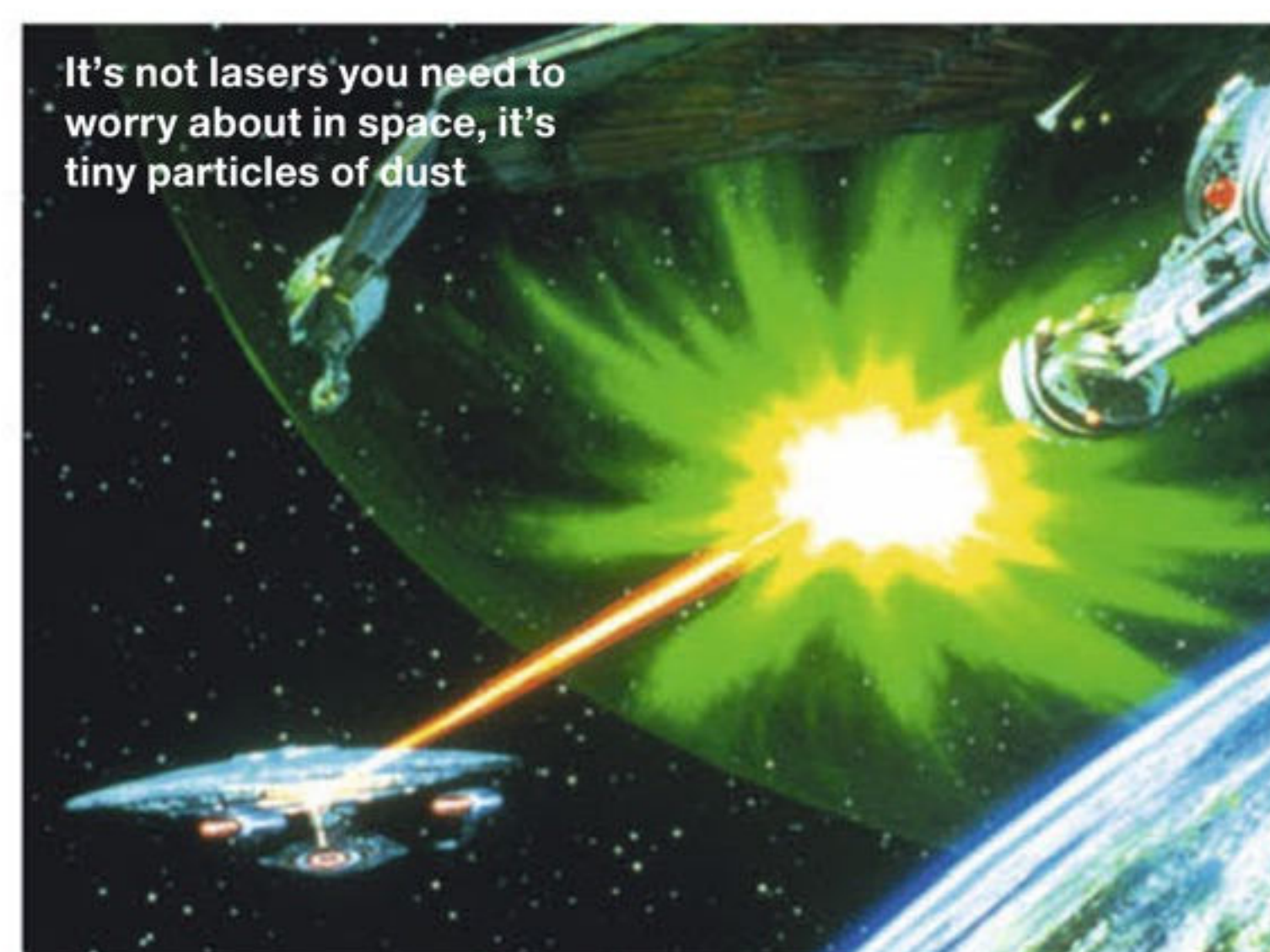
The energy required to create a warp bubble was once estimated to be the equivalent of the mass of a galaxy (Einstein showed that mass and energy are interchangeable) and both mass and energy can shape space-time. Now it's thought that the energy equivalent might just be that of Jupiter. But we still have a long way to go; note that the biggest hydrogen bomb converted only a few kilograms of matter to energy.

Warping of space-time on the scale needed for warp bubbles is beyond mere 21st-century science, and actual experiments are far off – the concept is still only theoretical. The dilithium crystal-powered warp drives in *Star Trek* remain, for now at least, just another plot device.



STEP 2 NAVIGATE DEEP SPACE

Picking a route is easy – the challenge is to find reference points and negotiate interplanetary hazards



It's not lasers you need to worry about in space, it's tiny particles of dust

The target star is in view, but where are you? To deduce your location, use triangulation to measure the angles between the ship and known stars. Alternatively, locate several pulsars – the rotating neutron stars that emit regular bursts of intense microwaves (pulses), with intervals as short as thousandths of a second. The ship's speed is determined by measuring the frequency of pulses, which will need to be adjusted using the 'Doppler shift' as the ship moves.

But the space between stars isn't empty: interstellar dust is a problem. While its grains may only be a millionth of a metre across, a starship travelling 10 lightyears will endure a thousand impacts on every square millimetre of its surface. On a trip to Alpha Centauri, the craft would be slowly, steadily eroded by such impacts, taking a 1.3cm layer off the hull.

One way to stop this would be to include a thin foil a few metres in front of the ship. Incoming dust particles would pass through the foil and emerge ionised (as charged electrons and ions), before hitting an electrostatic shield – a sort of 'force field', perhaps a charged grid. This shield would protect all parts of a starship behind it. Just a few thousand volts will deflect the electrons, while a million volts will deflect the ions.

Generating such an electrostatic shield in the vacuum of deep space is no problem. So the only remaining hazard is larger particles, which are very rare. We don't know how rare, however, and need better data from deep space to understand whether they're a true problem. But an ionizing laser pulse from the ship, guided by radar, could stop them.

Beamed energy sails

Spacecraft propulsion using sails was first proposed in 1610 by astronomer Johannes Kepler, after noticing that a comet's tail seems to get blown away from the Sun. Today, space agencies do already have craft with solar sails, such as Japan's IKAROS (Interplanetary Kite-craft Accelerated by Radiation Of the Sun), but these would take thousands of years to reach even a nearby star.

A 21st-century spacecraft that could genuinely achieve interstellar flight is the beamed energy sail, or sailship. The idea is to exploit the ability of electromagnetic waves to transfer power through space, producing force at great distances. The 'beamer' – the source of the beam, plus an antenna – projects a powerful laser or microwave beam onto a large sail. The sail would reflect this beam, picking up momentum and 'pushing' the ship away. Such a ship appears in *Star Wars Episode II*. Beamers would look like the satellite

receiver dishes we're used to seeing, only very much larger.

The expensive part is the beamer, which would be built in space from materials mined from the Moon or from asteroids, and positioned close to the Sun, where it could run on strong solar power. The best feature of beaming energy is that the heavy beamer gets left behind, while the light sail, carrying its payload of passengers and cargo, is driven far away. The beamer can then be reused for future missions. Like the 19th-century railroads, once the track is laid, the train itself is a much smaller expense.

The physics of sailships has been proven: the big problem is building the beamers and sails. The beamer might be thousands of kilometres in width, the sail hundreds of kilometres in area. Economic studies show them to be inefficient and expensive, but research currently underway will determine if the time for beamed energy sails may have come.

STEP 3

MAKE IT A SAFE, COMFORTABLE TRIP

As well as maintaining life support and social interaction, people will need to reproduce or stay in suspended animation

Lack of gravity causes astronauts to lose 1-2 per cent of bone mass per month. To provide artificial gravity by centrifugal force, spacecraft should spin at around one rotation a minute. The entire ship could rotate, or just part of it, as seen in *2001: A Space Odyssey*. Without bone mass and muscle tone, people wouldn't be able to walk when they arrived.

For the crew, the essentials of air, food, and water determine the volume of room required, meaning that private living space will be compact and public spaces will be emphasised. NASA recognises that astronauts can tolerate small spaces for short times – a coffin for an hour, a phone booth for a day. The decade-long occupancy of the International Space Station (ISS) shows that, over the long term, each person needs at least 100m³.

There are two approaches to maintaining the habitat. One is a closed, recycled ecosystem, where everything gets grown and processed inside. The other is to carry enough supplies for the voyage. But neither is possible by itself: a closed recycled ecosystem could fail, while the amount of supplies required for longer voyages would be prohibitive. The optimum is to have about half the mass in each method. Air and water would be recycled, as on the ISS. Fresh fruit and veg would be grown in a hydroponic farm, while



Sigourney Weaver in 'hypersleep' (suspended animation) in *Alien*

frozen and dehydrated food would act as a backup. But no closed ecosystem has so far been made to work on Earth: there are so many sub-systems in ecosystems that building one in a small space is beyond our present abilities.

Beyond survival challenges, there are the psychological issues associated with confinement, limited companionship and social dynamics. To deal with these, the advice is to stay busy, keep a steady day-night schedule and watch your health – all pretty unsurprising. But in a crewed starship, there would be both sexes, especially if you're planning to colonise a planet, which raises awkward questions regarding sexual relations and reproduction.

One way to help time pass smoothly is stasis, or suspended animation, as seen in the film *Alien*. Body metabolism would be slowed by cooling and reanimated on arrival. Biochemist Mark Roth is studying metabolic slowing to buy time for people awaiting treatment after suffering trauma. Stasis would reduce the need for supplies and eliminate psychological issues.

STEP 4

LAND ON AN ALIEN WORLD

Make advanced preparations for landing, before setting up a base and terraforming the planet



Exploration

Although a starship carrying humans would head straight for a target planet, along the way it might also drop small probes into the orbits of other interesting planets in the same star system. By studying the spectra of light from a planet's atmosphere, we would be able to pick out interesting compounds such as water and methane. And if we find out-of-equilibrium chemistry, it might indicate life.

What type of world would we choose to explore? If there's an alien ecology, then there are dangers from it, and dangers to it. Here on Earth, the New World suffered from Old World diseases when they were introduced 500 years ago, while New World diseases have also spread into the Old World. In HG Wells' *War Of The Worlds*,



Martian invaders were stopped by the common cold. So early landings would be robotic, followed by explorers in protective suits. Some dangers could be subtle, however, taking a long time to emerge.

Colonisation

We have no experience in the encounter of two completely different biologies, so perhaps the best planet to settle on is one with no life forms. Colonists could introduce terrestrial life if the planet has conditions that are close enough to Earth's.

That means a planet at least within the 'habitable zone', the distance from a star where water is a liquid. Land and water are essentials, as is an atmosphere that

In Aliens, terraforming takes mere decades. In reality, it would take centuries at least

can be modified so we can breathe it. We could even recreate the evolution of life on Earth, and start with the introduction of microbial life. To thrive and survive in very hot, very cold or chemically hazardous environments, we might introduce 'extremophile' microbes that produce CO_2 . As conditions improve, plants could be added to photosynthesise and turn the CO_2 into oxygen.

What this amounts to is planetary engineering, known as geoengineering or terraforming. In the film *Aliens*, the fictional Weyland-Yutani corporation is involved in "building better worlds", and terraforming takes mere decades. In reality, it would take much more time – centuries at least. But once completely terraformed, the planet would indeed resemble a second Earth.

STEP 5 MAKE FIRST CONTACT

What we'd do if we encountered
an advanced alien civilisation

In *Star Trek*, there's a handy set of guidelines for contact between alien races. It dictates, for example, that an advanced race shouldn't interfere with the development of alien civilisations. Once a race becomes sophisticated enough to develop interstellar travel, first contact is made on a case-by-case basis.

No official protocol yet exists on how humans should deal with an alien civilisation, should we find one, but the first encounter we have with them may not differ fundamentally from the first meetings between different cultures on Earth. On the good side is the example of Squanto, a Native American who taught the Pilgrims to catch eels and plant corn. On the bad side, when Captain Cook

landed in New Zealand, the Maori greeted his party with the Haka dance, which the English took as threatening. The English fired upon them instead of offering a palm branch, as was the Maori custom.

Aliens may look like spiders or snakes that we might reflexively recoil from, or they might look like birds or fish – but intelligent, so we'd need to be careful about preconceptions. Any gifts we bring would need to be decontaminated beforehand, and they may not even understand the concept of gift-giving. Nothing can be assumed.

A key aim of a first contact protocol is to avoid hostility from developing. In an utterly alien culture that would be hard to avoid: we'd be entering

*Aliens may
look like
spiders or
snakes,
which
we might
recoil from*

their territory, which could well be considered invasive or dangerous, and we'd be wearing protective suits to avoid cross-contamination, which may seem forbidding to them.

One thing we can assume: aliens will be curious about the same things as us. What do we look like? Are we a threat? How do we live? And, perhaps worryingly, what could they get from us? ■

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Professor Bruce Hood

Me, myself and I

You made the decision to read this interview, right? Wrong.
Prof Hood explains why your sense of self is merely an illusion

WORDS: ANDY RIDGWAY

Focus: We commonly believe in the idea of the 'self' – an individual making decisions in our heads. Do you have a different view?

Bruce Hood: Neuroscience gives us a big clue as to what's going on. When we make a decision, such as "I will pick up that cup of coffee," we feel that someone, our *self*, has initiated that decision. We think we have the mental thought first and then the action follows. But we know from neuroscience that it can be the other way round. Something in our body wants a cup of coffee and the motor system inside our brain prepares for the movement. It is about half a second later when we get this conscious thought, "I'll pick up that coffee". In fact, a lot of consciousness is after the fact. This shows us that what we think of as a 'self' making decisions, is not what it seems.

F: So how do we actually make decisions?

BH: There are a multitude of influences that contribute to our decisions, many of which are unconscious. We get the output of those influences and interpret it as a decision we've made.

You can imagine those influences as the strands of a web and our perception of the 'self' is what sits in the middle. It's the structure that emerges from all the competing factors. One way I like to describe the self is that it's like an illusory contour – a visual illusion. Take the one in which we see a square made out of the edges of lots of other shapes. There is no square there, but we still think we can see it. The self is the same. We can see something in the middle of the web, but its shape is determined by everything around it – all these influences. It's this illusory self that we think is making all the decisions.

F: Would some of the strands of the web be made up of past experiences and our genes?

BH: Exactly. There are unconscious influences from the past and there are unconscious influences at that moment in time.

F: If our 'self' is simply the sum of all of these influences, does that mean it's very fragile?

BH: Yes, you can see the self fragmenting in city centres at the weekend when people drink alcohol. They do things they wouldn't necessarily think they would. Alcohol affects the frontal lobes of the brain, areas involved with planning. When you are disinhibited, the drives of aggression and sexual interest – two of the strands of the web – have a stronger influence. That's when people say "I wasn't myself last night, it was the wine talking". It's as if they have vacated their body and gone somewhere else.

Clearly they haven't gone anywhere, it is just that this coherent sense of an upstanding citizen has been compromised by the fact that a drug can fragment our control processes.

F: Why do we need to maintain an illusion of self?

BH: It would be difficult to interact with others if we didn't treat them as individuals with a self, because you'd be forced to treat them as a collection of unconscious processes with a whole history that we can't possibly know about.

F: There are lots of self help books, but if we're simply a sum of influences, does that mean we can't change the self?

BH: Well, these books are another source of influence on our decisions. We are all ultimately malleable and influenced by others, but we must not be fooled into thinking that there is an individual inhabiting the

"One way I like to describe the self is that it's like an illusory contour – a visual illusion."



body that has some kind of free will and control over what's happening.

F: Do you think that knowing that the self is an illusion can help us?

BH: Much of the world is an illusion. We are blind for three to four hours of every day: every time we move our eyes, the world shuts off but we are never aware of it. There are many illusions that the brain creates to provide an optimal way of seeing the world. So I don't think you can get rid of the self. But understanding that we are a complex system that produces this output of the self helps us to understand bizarre behaviour. It explains why people go off the rails. There are all these impulses, these hidden drives, and these can occasionally emerge at times of heightened stress or intoxication. You will see facets of personality that most people try to keep under wraps.

F: Is thinking of the self in this way a means to be less harsh on ourselves?

BH: In the West, we tend to heap lots of praise and a lot of blame on individuals. People in the East tend to be more collectivist. I'm not here to advocate one system over the other, but in our Western culture we are all too quick to call others losers when there are so many factors that could explain why they haven't managed to achieve like everyone else. ■

Watch Bruce Hood in 'Christmas Lectures 2011 – Meet Your Brain' at: <http://richannel.org/christmas-lectures>

The Self Illusion: Why There Is No You Inside Your Head by Prof Bruce Hood goes on sale on 19 April and is published by Constable





Fantasy FOOTBALL

With the Champions League final and Euro 2012 just around the corner, **Nic Fleming** investigates the technology that will transform the beautiful game

FIFA president Sepp Blatter once said that football is a game “for human beings”. In other words, technology that would help referees make decisions has no place in the sport. But after a series of controversies in the 2010 World Cup, including a disallowed Frank Lampard goal in England’s 4-1 defeat to Germany (yes, the ball *did* cross the goal line), the tide turned.

Right now, two systems, GoalRef and the well-known Hawk-Eye, are being put through rigorous tests to see whether they can effectively determine if the ball has crossed the line in a match. A notification would then be sent to the ref’s wristwatch. If either system passes the tests, which end in

June, they could be approved by the International Football Association Board the following month and used for the first time in the 2012-13 season.

The approval of goal-line technology would be a significant step forward. But it’s just the tip of the iceberg. Tech has been developed, or is in development, that could tell referees everything from whether a player really did dive in the penalty box to which four-letter word they have just been subjected to.

In this *Focus* guide to football technology, we look at the tech that could transform refereeing as well as innovations that will revolutionise other aspects of the sport – making the beautiful game an even more enjoyable experience for fans. ►



BETTER REFEREEING

How technology can eradicate those infuriating decisions

Laser-guided players

It's almost a given that players taking throw-ins and free kicks will try to take them from further forward than they should, while walls defending free kicks also often inch forward. So with other systems able to determine precisely where throw-ins and free kicks should take place, these positions need to be physically pinpointed. Steve Haake, Professor of Sports Engineering at Sheffield Hallam University, says the ideal tool would be high-powered lasers. "These can be located in the stands and when there's a free kick they'd draw a 10-yard circle around the point where the free kick is being taken," he says.

Ball tracking

The German company behind the goal-line technology GoalRef has also developed RedFIR, a system that can track the real-time position of the ball and players with pinpoint accuracy, helping with offside, corner and throw-in decisions. The Fraunhofer Institute for Integrated Circuits has developed a robust RFID (Radio-Frequency Identification) tag, a small electronic device that sits at the centre of the ball transmitting signals 1,000 times per second. Other tags can be worn behind players' shin pads. The location of the ball and each player are calculated from the time it takes these signals to reach four of 12 receivers around the pitch.

Anti-dive shin pads

Theatrical 'dives' could soon be a thing of the past. UK technology company Smallfry tested prototype shin pads last year that contain an accelerometer to measure the force of any impact, making it easy to determine whether a striker was in fact brought down by a crunching tackle, or performed a dive Tom Daley would be proud of. Alarm signals could be sent to a device carried by the ref. Smallfry MD Steve May-Russell says later versions would need to be linked to a positional system such as RedFIR, to ensure that any impact occurred while an opposing player was nearby – to prevent players sneakily kicking themselves.

SHOULD REFEREES GET MORE ASSISTANCE?

FOR TECHNOLOGY



DERMOT GALLAGHER
Former Premier League referee and current assessor of referee performance for the Professional Game Match Officials Board

"I think every referee that officiates at professional games wants goal-line technology because it would alleviate a massive problem. I welcome technologies to help with decisions that are matters of fact such as whether a ball has crossed the line, but not for decisions that are subjective, such as penalty calls. The problem with having impact sensors is that there does not have to be physical contact for there to be a foul."

AGAINST TECHNOLOGY



JOHN NICHOLSON
Football365 columnist and the author of *Footy Rocks*

"If we introduce technology to judge one aspect of the game, there will eventually be calls for it to judge all aspects, so it has to be all or nothing. In reality it would mean you would always be stopping to analyse whatever machine is being used so the game would be constantly being halted. Inevitably, there is always going to be an element of human error in football. It's okay for mistakes to happen in sport."

Abuse recognition

Rather than relying on refs picking up on four-letter words or racial abuse, speech recognition software could do the job. Professor Phil Green, of the University of Sheffield, rigged up a demo system in 2010 with players fitted with close-talking microphones, which are worn next to the mouth. Future versions could use tiny mics embedded in football shirt collars. The sound waves produced when the player speaks could then be compared in real-time with those generated when offensive words are uttered. "It would be expensive and technically challenging, but potentially viable," says Green.

Virtual lessons

Referees at the 2010 World Cup were provided with a variety of multimedia training resources including videos, 3D animations and trivia games, in an attempt to standardise decisions. Virtual reality simulators are being deployed in growing numbers of fields, and Prof Haake says tomorrow's referees can expect interactive training using VR goggles and surround sound. "Virtual worlds can include the sight and sound of 40,000 people shouting at you for a penalty," he says. "So it is a highly immersive environment in which to test reactions and decision-making."

WHY REFS GET IT WRONG



CROWD CONTROL

Home teams tend to win more matches, so US economist Tobias Moskowitz and journalist Jon Wertheim tried to unpick what's going on. Using statistics, they ruled out possibilities such as crowd support inspiring the players, saying that instead, in football and several sports, refs favour home teams in judgement calls. Rather than being deliberately biased, the pair think refs subconsciously pick up on the crowd's mood.



DIRECTIONAL BIAS

People from cultures that read from left to right find movement in that direction more 'normal'. Volunteers shown photos of tackles, both in their real orientation and flipped 180 degrees, called more fouls when they depicted right to left movement. The University of Pennsylvania neurologists behind the study say a ref seeing the same incident from different vantage points could make different decisions.



THE HEIGHT EFFECT

Psychologists have shown that we associate tall people with concepts such as aggression and dominance. Dutch researchers, who analysed 123,844 fouls in seven Champions League and German Bundesliga seasons as well as three World Cup tournaments, found more penalties were awarded against tall players. The effect was strongest when the height difference between two players was greatest.



PENALTY COMPENSATION

From 1963 to 2006 there were 12,902 games in the top tier German Bundesliga. In 146 of these, the away team was awarded the first of two penalties. In these games, the second penalty was 12 times more likely to be awarded to the home team than the opposition, thanks to what the study author, psychologist Wolf Schwarz of Potsdam University, calls the "compensating tendencies" of referees.

BETTER MANAGEMENT

Equipping coaches with improved tools and data will mean better teams and more entertaining games

Eliminating bad refereeing decisions is one thing; stopping players developing a 'red mist' in the heat of battle is quite another. But technology may help managers tame hot-headed players who have a tendency to get themselves sent off. This season, Premier League club Manchester City will begin testing a system developed by British company Myndplay to see if it can improve self-control.

Myndplay's technology measures the state of mind of footballers while they play interactive games. Progressing in the games depends on being in a relaxed and focused frame of mind. The idea is that repeating the game should help players to teach themselves to keep cool.

"If you can train yourself to maintain focus and stop yourself getting frustrated, that will naturally improve performance, whether that is through receiving fewer red cards or scoring more goals," says Mohammed Azam, Myndplay Managing Director.

Electro-encephalography (EEG) sensors placed on a player's head detect electrical activity in brain cells, or neurones. Collections of neurones fire in different rhythmic patterns, and these have names, such as alpha and beta

waves. They've been found to show whether someone is relaxed or agitated.

It's not just player's minds that are being scrutinised by new innovations. The revolution in sensor technology, allowing for smaller devices, is also paying dividends. For instance, Catapult Sports, an Australian company specialising in athlete tracking, sells compact sensors worn by players during training in a pouch on the back. GPS and accelerometers enable parameters such as distance run, acceleration and deceleration to be monitored. And the latest models also have gyroscopes and magnetometers, which provide information on orientation and small movements. Managers can watch animations of training games, giving them a useful tool for tactical analysis.

Catapult is also developing an algorithm that would allow fitness coaches to use data from these sensors to analyse their players in finer detail, making it easier to monitor injuries. "Coaches can see whether or not players are slowing down at the rate they normally do, or favouring one side when they change direction," says Catapult's Luke Millar.

Prozone: the manager's tool

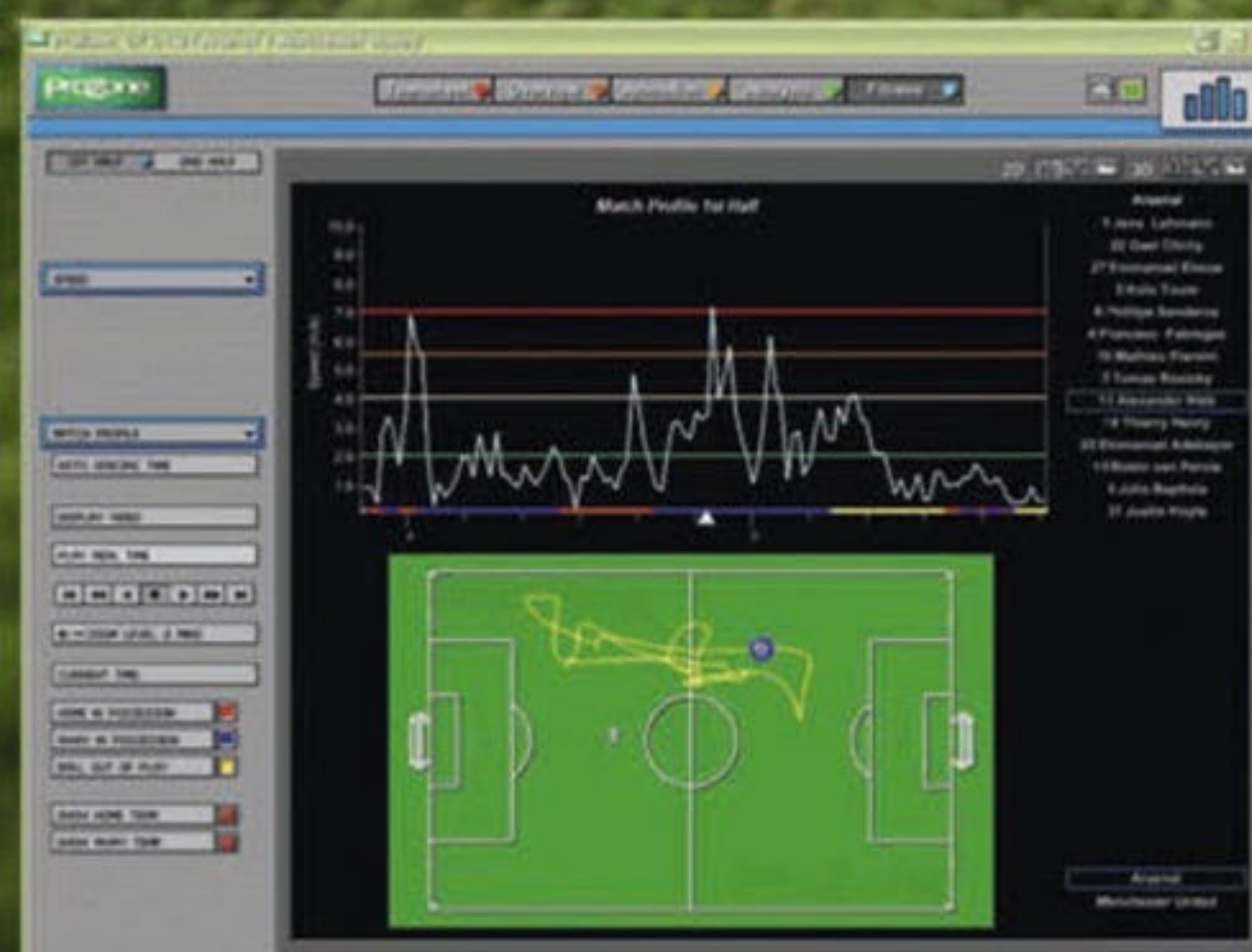
The idea of tracking players to monitor their performance on the pitch isn't new. Many clubs in the English Premier League and Championship already use a system from British sports performance analysis company, Prozone.

Prozone's system provides data from competitive matches. The movements of players, the referee and the ball are tracked using eight to 12 cameras positioned around the stadium. That raw information is then processed by Prozone to provide managers with stats, 2D animations and video clips. The camera system can also be deployed at a club's training ground too.

The company's technology is well established, but developments are still being made. Prozone has made use of Sony's 'intelligent object detection' system. This can recognise, for instance, when a

pre-determined number of players enters the penalty area, so that it can differentiate a goal kick from a busy corner. More cameras can then zoom in on the action, capturing it in more detail, for detailed analysis later on.

Prozone is the current tool of choice for many football managers





BALLS OF THE FUTURE

Even the football itself could be set for a high-tech overhaul



On the ball coaches

As in many professions, data is king. Last year, German company Cairos Technologies launched its Bemeister ball, which contains a pressure sensor and a magnetometer. These sensors can tell coaches how much power players are putting into passes or how much spin is applied in free kicks. If these sensors were combined with RFID chips that can show the location of the players and ball (see 'Ball tracking', p60), managers would have a raft of information about players' every move in training.

More fun for fans

If accelerometers, magnetometers and RFID chips in footballs were allowed in matches, fans could interact with the game in new ways. "There will be new bets based on real-time performance data, such as who will shoot the hardest in the next 10 minutes," says Christian Holzer, CEO of Cairos. Data derived from sensors could allow realistic 3D renderings of real matches to be used as games. "Fans will be able to replay the game once they get home on their PlayStation or Nintendo," adds Holzer.

STATS AT THE MATCH



Screens in the arms of seats and smartphone apps will transform spectating

Many fans already carry a device into the stadium that could significantly enhance their enjoyment of the game – their smartphone. Gone are the days of having to take a portable radio into the ground to keep track of how rivals are doing on a Saturday afternoon – supporters can now check the scores online.

But that's just the start. German company Cairos predicts it will launch an augmented reality football app for mobile devices within five years. You'd simply tap the player that's on your screen as you hold the phone up to the pitch to reveal real-time statistics, such as how quickly they're running and how many goals they've scored this season. Cairos's app will initially be launched in Germany and then potentially rolled out elsewhere. The data for the software will come from VIS.TRACK, a player tracking and data service based on video analysis run by Cairos and used by leading German sides.

Some experts also believe football will follow American sports such as ice hockey in installing high-definition personal screens into seats in stadia to provide an additional viewpoint. "In the US there is a much greater focus on improving the in-stadia experience," says Blake Wooster, Head of Business Development at football performance analysis company Prozone. "In the future, football fans here might well have a second screen in their seat on which they can select their own TV footage, look at the match-day programme, pull up GPS-based stats, make predictions and manage their fantasy football team."

As well as being able to get a better view of the action, fans would be able to order a half-time drink from the comfort of their seat using the screen.



THE BEST SEAT IN THE HOUSE

Q&A: GRAHAM THOMAS

Panoramic cameras and vibrating seats will transform how we watch football in our living rooms, says the Principal Research Engineer in the BBC's R&D department

Is technology being developed for the increasingly large TVs we're buying?

We're working on super high vision, which is 16 times higher resolution than today's high definition. We're also developing panoramic cameras with a much wider view of the pitch. With bigger screens and wider views, viewers will just be able to turn their heads to watch different parts of the football field, so there will be less need for camera movement.

Will there be new ways to view key incidents?

We've been working on systems that will automatically generate complete 3D models of the players from footage from at least six cameras, allowing incidents to be seen from a wide range of viewpoints. Ultimately we might be able to synthesise the goalkeeper's view of a shot or a referee's view of a foul.

What about technology for phones?

It's often said that the best way to watch football on TV is to just sit back and use the shot that has been selected for you by a trained director. There's a lot to be said for that, but because of the diversity of screen size the best shot may depend on whether you are watching it on a mobile phone, in HD, 3D or on a huge wall-mounted screen. It would be too expensive to have separate production crews for all the different formats, so we are looking at some level of automation of the production process.

How will audio improve?

To make the experience much closer to that of sitting in the stadium, we need immersive audio that goes beyond surround sound. In a stadium you get sounds from above and below, not just left, right, front and back, such as reverberation from the stadium roof. We've already done

some trials on that. We are also looking at methods of delivering realistic 3D sound to headphones. If you can learn the characteristics used by the brain to know the direction from which sounds are coming, you can model them and fool the brain into thinking that particular sounds are coming from different directions.

When will we get live holograms?

It is certainly possible to create holograms which appear to have depth on a screen. To produce something in mid-air without a screen behind it is possible with high-powered lasers projecting into a thin film of mist, but to produce the classic 'Princess Leia' hologram effect, as it is often called, is technically difficult, or even impossible. I would also argue that you would probably get a better viewing experience from a big screen display than from a holographic God's-eye view of the match with 2-inch tall players on your coffee table.

Will anyone still go to matches?

Well, people like hearing the crowd cheer and having drinks spilt on them! So I expect a lot of people will still want to go to matches to get the social experience and excitement of actually being there. That said, there has also been work on sharing the home viewing experience with friends elsewhere, using a video conferencing system and very realistic audio.

But no virtual beer-spilling technology so far?

No, but we've looked at ways to make the viewer's seat shake to simulate the feeling when the crowd jumps up when there's a goal. I suppose you could put your drink on a table that shook to recreate the pleasure of having it spilled at a real match if you wanted to. ■

Nic Fleming is a freelance journalist based in London

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THE SCIENCE OF DOGS

From the origin of the species to understanding genetic diseases, **John Bradshaw** shares some surprising insights into man's best friend

The dog has lived at man's side for longer than any other species. Our relationship with dogs began over 15,000 years ago, at the dawn of agriculture, or even earlier. Although it isn't possible to disentangle the dog's precise contributions to civilisation, it's also difficult to imagine how we could ever have managed to herd or hunt other animals so effectively without them.

Many prominent scientists have shown an interest in domestic dogs, beginning with Charles Darwin, who both documented their behaviour and used them as a model for natural selection. In the 20th century, Nobel prize-winning zoologist Konrad Lorenz

was fascinated by the interactions between dogs and people, while the geneticists JP Scott and JL Fuller spent 15 years studying the inheritance of behaviour.

Then, until about 15 years ago, science lost interest in the dog, regarding it as inferior to genuinely wild animals. But the 21st century has seen something of a renaissance in canine science, with researchers across the world addressing such issues as whether dogs have a special form of intelligence, the extent to which domestication has changed them from their ancestor the wolf, and even what their emotional lives might be like. We now know more about dogs than ever, and some of the findings are far from obvious. ►



Dogs probably evolved from a more docile relative of today's wolf

ORIGINS

From wild ancestors to household pets

WHY WERE DOGS DOMESTICATED?

We probably didn't domesticate them deliberately. Dogs became domesticated earlier than any other animal, around the time that humans were beginning to make the change from hunter-gatherer to farmer over 10,000 years ago. DNA analysis shows that the dog is descended directly from the wolf.

Modern wolves don't behave in a way that Mesolithic man could easily have controlled, however, so there may once have been wolves that were more docile – wolves that have since gone extinct in the wild, but whose DNA lives on in today's dogs. Those wolves may have taken to scavenging around human settlements, and at times their cubs may have been adopted by the villagers – taking young animals from the wild to raise as pets is still widespread in hunter-gatherer societies.

These hand-raised cubs could be socialised and subsequently trained. Only then could these early dogs have become useful to their owners, and then been bred to fill roles such as helping with guarding and hunting. Thus the 'domestication' of the dog probably started off as an accident – but a beneficial one for both the wolf and also for mankind, whose partnerships with dogs have helped shape civilisation.

WHEN DID DOMESTICATION BEGIN?

The earliest definitive evidence is a burial, in what is now northern Israel, of a man whose hand is resting on a puppy. The puppy's skeleton is distinctly different from that of a wolf cub of the same age, its teeth in particular, and so it must have been a dog. Its deliberate positioning in the grave suggests a special relationship with the man. Thus we know that by the time of this burial some 12,000 years ago, dogs already played a part in society. But the events that led to full domestication remain unclear – we cannot say for certain where they took place, nor how long ago.

Last year, archaeologists discovered a 33,000-year-old canine skull in Siberia. Although the shape was distinctly dog-like, its massive teeth were similar to those of a wolf. Another skull, excavated at Goyet in Belgium over a century ago, has recently been dated by palaeontologists at 31,000 years. Could these canines from over 30,000 years ago be the ancestors of today's dogs? Possibly not: the most likely scenario is that these early attempts at domestication (if that's indeed what they were) failed because humans were driven south by the most recent Ice Age 24,000 to 13,000 years ago. Hence dogs had to be reinvented once the climate had improved again.

WHERE DO DOGS COME FROM?

The archaeological evidence points firmly to the initial domestication – or at least one of the early domestications – occurring somewhere in Western Asia, an area that we now refer to as the Middle East. Since the complete DNA sequence – the genome – of the domestic dog was mapped in 2005, it's become possible to reconstruct the course of domestication by comparing the DNA of different kinds of dog, both with each other and with that of wolves from different parts of the world. These comparisons show that the DNA of most breeds of dog is closer to that of Middle Eastern wolves than any other, which confirms the archaeology.

Geneticist Peter Savolainen of the Royal Institute of Technology in Sweden, however, is convinced that dogs originated in southwest Asia. Species often lose diversity in their gene pool as they spread to other parts of the world, so diversity can point to a place of origin. The highest genetic diversity occurs in villages south of the Yangtze River, where dogs have unusual types of DNA that could only come from local wolves; European dogs don't carry unusual DNA from wolves from the Middle East. Savolainen points to poor archaeological coverage in southwest Asia to explain the lack of corroborating evidence from dog burials.



EVOLUTION

Breeding dogs of all shapes and sizes

The division of dogs into breeds is, on an evolutionary timescale, a very recent phenomenon. For the first few thousand years of their co-existence with man, dogs still looked wolf-like, even though their behaviour must have been quite distinct from that of their wild ancestor.

But by the time people first started drawing pictures of dogs some 5,000 years ago, several types had already emerged: long-limbed, long-nosed sighthounds, heavily built mastiffs for guarding, hound and terrier types, and even dogs bred as food. For a long time, dog breeding remained unregulated, with little input from science. It wasn't until the late 19th century that pedigree breeds were established, along with the idea that a dog could only be given a pedigree if its parents, grandparents and great-grandparents were all from the same breed. Selective breeding based on written 'breed standards' quickly led to the establishment of the 400+ breeds that exist today.

This selective breeding has, in some cases, been taken to the extreme, compromising the dogs' welfare. The English bulldog has gradually been bred into a shape that makes walking and breathing difficult, and they may need assistance when mating and giving birth. More insidious, however, is the appearance of a host of inherited disorders due to excessive inbreeding.

While the genetic diversity of dogs as a whole is healthy, within some breeds you can't find individuals that are more distantly related than the equivalent of first cousins. Such a reduction in genetic diversity inevitably leads to inherited diseases due to matings between 'carriers': two



dogs, both outwardly healthy, but each carrying one copy of a defective gene. For example, over 60 per cent of Lancashire heblers may carry a mutation that can lead to blindness.

One solution could be to allow limited cross-breeding. In Dalmatians, defects in genes linked to uric acid metabolism lead to dermatitis, as well as kidney and bladder stones. But by crossing Dalmatians with an English pointer, geneticist Dr Robert Schaible of Indiana University managed to eliminate the defective mutation.

Dogs feature in man's earliest paintings – like this 3,000-year-old example from Khao Pla Ra, Thailand



ABILITIES

How dogs rate in the brains department



SOCIAL INTELLIGENCE

Dogs outperform all other animals in their ability to attend to people. Even chimpanzees are difficult to persuade to follow simple human gestures, such as a pointing finger, but dogs are born with a powerful urge to learn as much as they can about how people behave. Dogs are fascinated by human faces, looking not only for signs of approval or disapproval, but also paying attention to the direction their owner is looking in. Behavioural zoologist Dr Florence Gaunet has found that many guide dogs still follow their blind owners' 'gaze' even though it's unlikely to be a reliable cue.



UNDERSTANDING THE PHYSICAL WORLD

Dogs can often seem clueless about how their physical surroundings work. In a study by psychologist Dr Britta Osthaus, dogs were presented with a choice of two handles where only one was attached to a piece of food by a length of string – most dogs persisted in pulling whichever handle was nearest the food, rather than pausing to work out which string the food was attached to. Dogs also seem incapable of thinking backwards and forwards in time, neither reflecting on the past nor planning for the future. This explains why dogs get so distressed when they're left alone: they have no instinctive concept of the owner's eventual return.



SENSE OF SMELL

Dogs have hypersensitive noses compared to ours, and new uses are constantly being found for their ability to smell what we cannot. For example, the charity Medical Detection Dogs has trained animals to alert people with brittle diabetes that their blood sugar has reached a dangerous level – even waking them in the middle of the night if necessary. Dogs also have a second olfactory apparatus, the vomeronasal organ, which is connected to the outside world by a pair of ducts running from just behind the upper incisors up to the nostrils. Far less is known about this organ, but it's probably devoted to the analysis of the smells of other dogs.



Dogs can follow simple human gestures – useful for tasks such as sheep herding



THE TRUTH ABOUT DOGS

Science is overturning conventional wisdom

DOGS DON'T BOND WITH EACH OTHER

Domestication has radically changed the dog's notion of 'family'. To the wolf, the family is all-important; wildlife biologist David Mech has shown that the typical wolf pack consists of parents and their grown-up offspring, who stay with them to help raise the next generation of cubs. Although descended from wolves, dogs appear incapable of organising their lives to bond with each other in this way. Even free-ranging dogs, such as the Australian dingo, don't form close-knit family packs, but breed independently instead. And for pet dogs, it's the people around them, not other dogs, that are the most important elements of their 'family'.



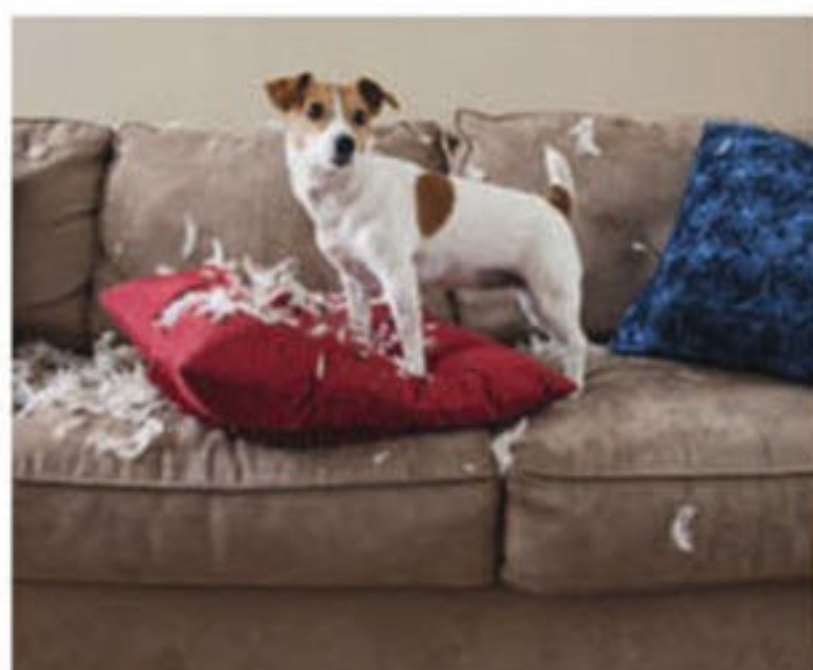
THERE'S NO SUCH THING AS 'TOP DOG'

The concept of the 'dominance hierarchy' has been applied to dogs in a way that biologists never intended. Dominance is a useful way of summarising which one of a pair of animals usually wins when they compete over something. But animals (except possibly primates) don't think about achieving 'dominance' as an end in itself. Behavioural biologist Rachel Casey has a simpler explanation: for dogs, each encounter with another animal – including a human – is simply motivated by whatever's at stake, whether it's a tasty treat or a pat on the head. Of course they'll choose their tactics based on what they already know about the other animal, but they're not motivated by a desire to take control.

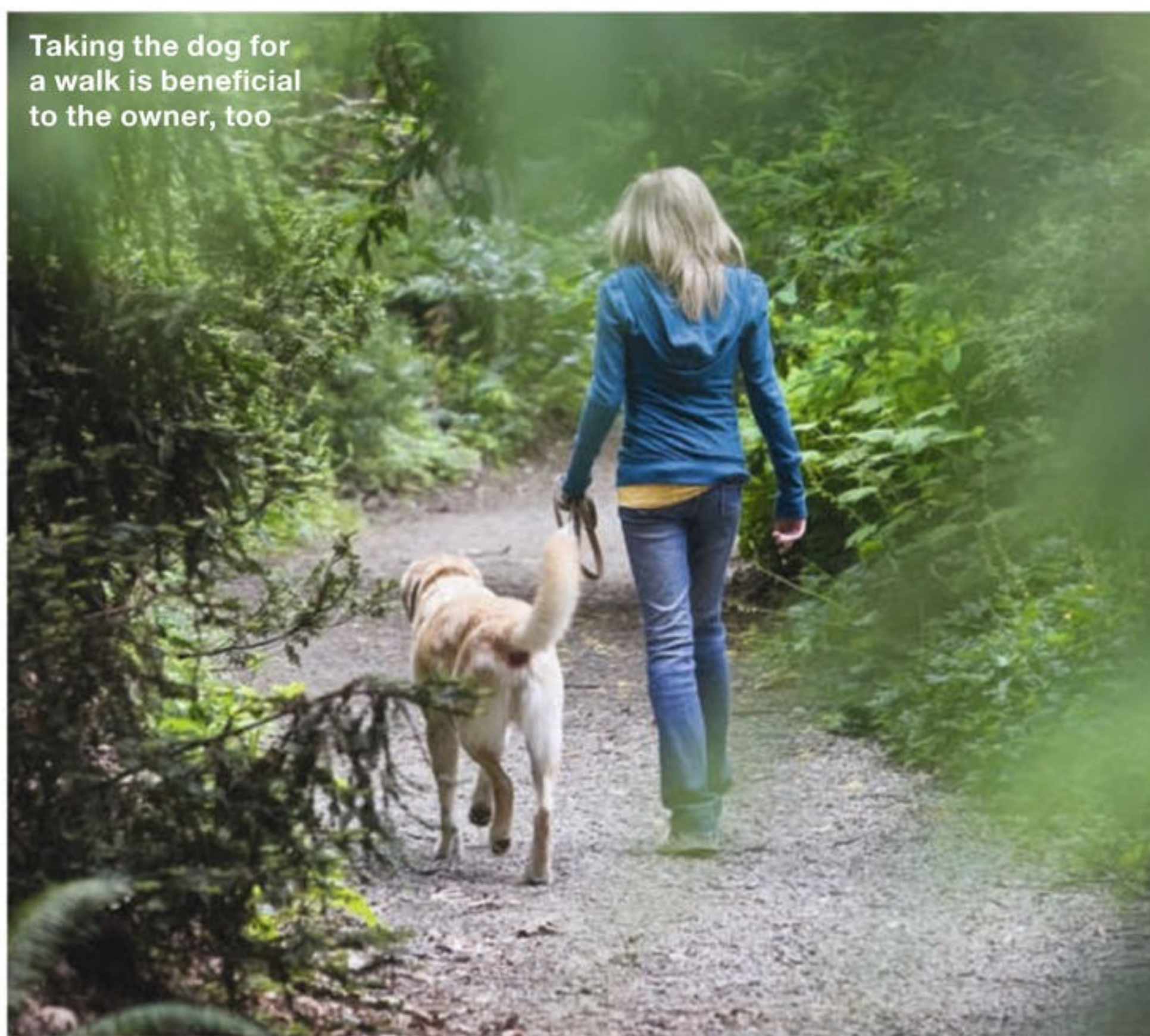


DOGS CAN'T FEEL 'GUILTY' FOR BAD BEHAVIOUR

A dog owner who returns home to find teeth marks in her favourite shoes may be forgiven for thinking that her dog 'looks guilty' for what they've done. Yet a clever set of experiments conducted by cognitive scientist Alexandra Horowitz has shown that dogs also adopt their so-called 'guilty look' when owners are told that their dogs have done something wrong – even when they've done nothing of the kind. The dog's 'guilty look' is nothing more or less than the anticipation that their owner is about to punish them – and they have no idea what for.



Taking the dog for
a walk is beneficial
to the owner, too



DOGS & HUMANS

Modern canines offer more than just companionship

The dog's role in human society has changed radically over the past 100 years. Working dogs, for instance, now make up only a small fraction of the population – and most of those are kept for companionship.

While dogs may be owned simply for the enjoyment of their affectionate natures, science is now revealing unexpected benefits to their owners' health. Stroking and talking to a friendly dog is not simply pleasurable: scientists at the University of Pretoria in South Africa found that it causes an increase in the 'love-hormone' oxytocin, and reduces blood pressure. Just taking a well-behaved dog for a walk can improve its owner's well-being in no less than three ways: from the exercise itself, from the social contact with other dog-walkers, and simply from exposure to the outdoors, which Jules Pretty from the University of Essex has shown to provide psychological benefits in its own right.

Dogs are also making a contribution to human health in another area: they're helping us to improve our understanding of inherited illness. Canine DNA sequences have provided invaluable insights into both how

genes control growth, and how they can malfunction to cause disease. Dog genes are easier to decode than human genes, which they resemble in many ways, because many of the genetic variations are isolated in particular breeds. By comparing the DNA of dogs of different pedigrees, it's proved relatively straightforward to isolate the genes responsible for the differences between them.

Geneticist Carlos Bustamante of Stanford University recently showed that as few as just six or seven regions of DNA are responsible for up to 80 per cent of the differences in height and weight between breeds. Moreover, within each breed, the lack of variation in DNA makes it easy to pinpoint which genes are defective in an inherited disorder, such as the bone cancer that is common in greyhounds, Rottweilers and Irish wolfhounds.

Understanding the science of dogs isn't only teaching us more about them, it's also revealing more about ourselves. ■

**Dr John Bradshaw is an
anthrozoologist and lecturer at
the Bristol Veterinary School**

Q&A

Your questions answered

Why don't birds freeze in winter?

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How long would it take to drive to the ISS?

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Could a Neanderthal be cloned?

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What was there before the Big Bang?

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What is the chance of an asteroid hitting Earth?

RICHARD GREEN, PETERBOROUGH

There are probably several million asteroids with the potential for smashing into planet Earth. But very large asteroids, which would have catastrophic consequences if they hit us, are thankfully very rare. Astronomers estimate that one of these monster asteroids (like the one that wiped out the dinosaurs) should fall to Earth once every 100 million years or so.

An object about 100m across should arrive every 1,000 years, although thousands of kilograms of tiny meteoroids land on Earth each day. However, most go unnoticed because they fall in unpopulated areas or into the sea. The chances of you being killed by an asteroid are very small indeed – much smaller than the risks you take driving a car or crossing the road. **AG**

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LUIS VILLAZON
Luis has a BSc in computing and an MSc in zoology from Oxford. His works include *How Cows Reach the Ground*

Why doesn't tooth enamel grow back?

DAN COOPER, PRESTON

Because the cells that produce it in the first place, called ameloblasts, are broken down after completing their construction job and never reappear. The enamel itself is 94 percent mineral, mostly a form of calcium phosphate. It contains only a little protein and no nerve supply. So if tooth enamel is broken or damaged by decay, it has no way to regenerate. **SB**



Do more men snore than women?

MIRANDA CALDER, WINDSOR

Yes, about twice as many. Snoring is sometimes caused by obstruction of the nose or by excessive growth of adenoid tissue, but some is a consequence of the fact that we humans can speak. When language evolved our voice boxes had to drop lower in the neck, creating a space behind the tongue called the oropharynx. The tongue, like other muscles, relaxes during sleep and it can then fall into this space, especially if we lie on our back, obstructing breathing or causing snoring. This space is larger in men than women, which may explain why men tend to snore while women are more likely to wake up. The result is that the men stay asleep and keep snoring... while we poor women lie awake and have to endure the noise. **SB**

Is dark matter distributed evenly throughout the Universe?

JOHN SUMMERS, BY EMAIL



Although dark matter makes up at least 83 per cent of the mass of the Universe, its composition and distribution are largely unknown. Our current theories say that, soon after the Big Bang, dark matter began to form the first large-scale structures in the Universe, which then collapsed gravitationally to form vast halos. These halos then attracted ordinary matter and provided a focus for the formation of galaxies. It is therefore expected that the distribution of dark matter should closely match that of ordinary matter.

Astronomers are trying to confirm this by imaging distant galaxies, looking for the minute distortions that should occur as their light passes through the gravitational fields of intervening dark matter. Early results show that galaxy clusters do seem to reside in dark matter halos, as expected. However, some regions of space appear to have high concentrations of dark matter but very little ordinary matter. These observations, and others, suggest there's still much to learn about dark matter and its role in the Universe. **AG**

When will there be a male contraceptive pill?

CAROL DAWSON, EDINBURGH

Not any time soon. Such a pill would need to neutralise all of the millions of sperm that men produce every day, because only one is needed to fertilise an egg. It should not destroy libido or prevent erections, and would need to be reversible so that men could stop taking it and return to fertility. Scientists have been trying and failing to achieve all this for decades. **SB**



How does paracetamol get rid of headaches?

DAVID NELSON, BY EMAIL

The exact mechanism is still not well understood, but it seems that paracetamol does at least two different things. One is to inhibit the action of the cyclo-oxygenase family of enzymes, which are involved with the body's inflammatory response. Inflammation can be a useful part of the healing process but in an ordinary headache, it's just a source of pain.

Paracetamol also affects a series of biochemical pathways called the endogenous cannabinoid system. This is involved with controlling appetite and our sensitivity to pain. Paracetamol blocks the re-uptake of a key neurotransmitter and thereby lowers our sensitivity to pain. **LV**

How does a knife cut?

NICHOLAS VLASTOS, BY EMAIL

Imagine squashing a block of butter with the palm of your hand. The butter has to move out of the way, so it is squeezed sideways as it gets flattened. Now use the edge of your hand, like a slow-motion karate chop. The edge has much less surface area, so the pressure is higher and it is easier to push your hand through. Also, because the edge is narrower, you don't need to push so much of the butter out of the way. Instead of flattening the whole block, you leave a narrow slot.

The blade of a knife is like a very thin hand. It applies huge pressure at the edge to push the material apart. When you try to cut a tomato, a blunt knife crushes a wide band of plant cells underneath it but a sharp knife will cut through a single line of cells, separating the long-chain cellulose molecules in the cell wall.

The sharpest knives are those with the thinnest edges. Obsidian (a form of glass) can be sharpened to an edge just three atoms across. Obsidian scalpels are sometimes used in surgery and have been found to produce less scarring, but a narrow edge is more delicate and the obsidian blades become blunt more quickly than surgical steel. **LV**

99

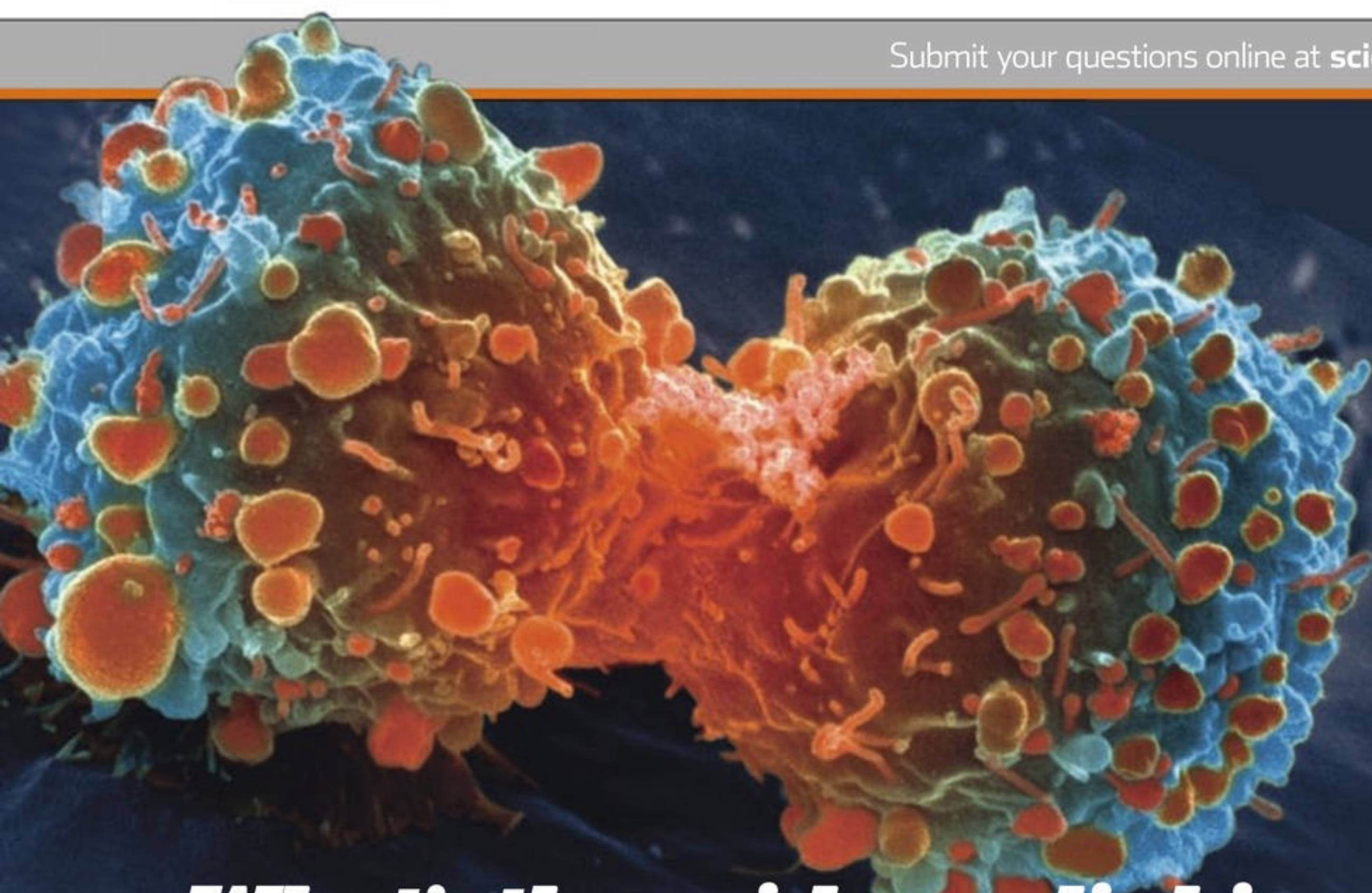
is the percentage of incoming light energy that a leaf is able to harness. The best solar panels can manage just 35 per cent

Why don't birds freeze in winter?

OWEN HARVEY, WORTHING

Lots of birds do freeze in winter. But natural selection operates quite ruthlessly against this premature end – any that freeze to death before they have raised offspring are eliminated from the gene pool. Birds have therefore evolved a variety of strategies to avoid this fate.

Like mammals, birds are warm-blooded and well-insulated, so provided they can find enough food, they can stay warm. Pigeons and crows are opportunistic scavengers, for whom towns and cities provide extra sources of food. Very small birds, like the wren, will build nests that are fully enclosed and even nest together in groups to conserve heat. And of course, lots of birds migrate. Many of the birds that we see in Britain in winter have actually migrated from even colder countries – the Russian robin, for example, is a regular winter visitor. **LV**



What's the evidence linking sugar to cancer risk?

DENISE MANNING, OXFORD

There's long been anecdotal evidence linking higher sugar consumption with an increased risk of cancer. Doctors working in Africa during the 20th century noted how increasing consumption of refined carbohydrates and sugar by the indigenous populations led to increased risk of what they termed the 'diseases of civilisation', such as diabetes, heart disease and some forms of cancer. More scientific evidence has emerged from studies

involving comparisons of the blood glucose levels of huge numbers of people and their cancer risk.

In 2005, a study of 1.3 million Korean people pointed to a link between sugar consumption and cancer risk, as did a European study published in 2010. However, the evidence is still far from compelling, as the increased risk figures are small and possibly attributable to other lifestyle factors. **RM**

Are probiotics really that good for your health?

RACHEL CORBEN, PENZANCE

Not especially. Probiotics are foods with live cultures of bacteria similar to the strains that live in our intestines. There is some research to suggest that they might be beneficial for sufferers of Crohn's disease and irritable bowel syndrome. They have also been found to reduce the duration of episodes

of diarrhoea in young children (though not in adults). But in 2010, the European Food Safety Authority conducted a review of the claims that probiotics strengthened the immune system and improved digestive health, and concluded that there was no sound scientific basis for these claims. **LV**

DID YOU KNOW?

The largest reef system in the northern hemisphere is the Belize Barrier Reef, a 963km² submarine shelf and barrier reef stretching from Mexico to Guatemala. Only Australia's Great Barrier Reef is bigger.



QUICKFIRE

How do low energy light bulbs work?

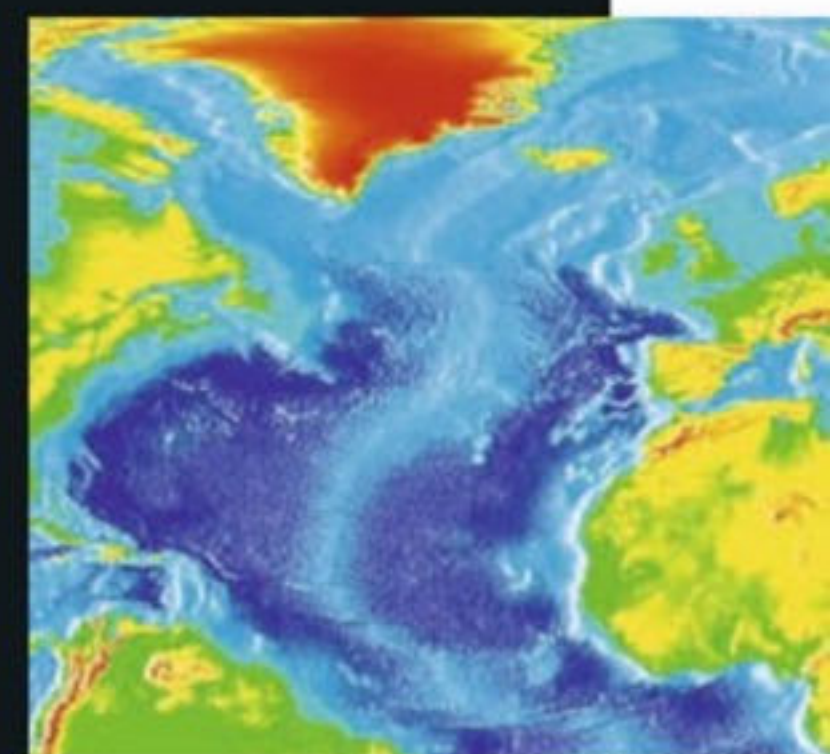
LAURENCE CABLE, BY EMAIL

A fluorescent light bulb contains a vapour of argon and mercury. The other key component is called a ballast, which regulates the electricity flowing into the device. When electrons in the current interact with the vapour, photons of light are released in the invisible ultraviolet portion of the spectrum. A fluorescent phosphor coating inside the bulb then converts the UV into visible light. **GM**

What percentage of the ocean floor have we mapped?

DAVID MULLOUGH, CIRENCESTER

Since 1985, satellite altimetry has mapped virtually the entire ocean floor. Although radar and microwave signals don't penetrate the water, the gravitational effect of undersea mountains deflects the surface of the ocean slightly. This can be measured to an average vertical accuracy of less than 3cm, but the horizontal resolution is only 10-15km. Survey ships have improved this to 10-metre resolution but only about 10 per cent of the ocean floor has been covered this way. **LV**



What is 'triboluminescence'?

PETE RANGER, CARDIFF

In 1605, Sir Francis Bacon noticed flashes of light bursting from blocks of cane sugar as he cut into them. Rip open a self-sealing envelope in the dark and you'll see the same effect. The cause of this triboluminescence – from the Greek for 'light from friction' – is still not fully understood. The most likely explanation is that when irregular crystals are torn apart, they also separate electric charges in the disrupted atoms, which then trigger tiny 'lightning bolts' of light as they re-combine. **RM**



TOP TEN HEAVIEST LAND ANIMALS

1. AFRICAN ELEPHANT

Weight: Up to 10,000kg (22,046lbs)
Largest recorded reached a height of 4m at the shoulder

2. ASIAN ELEPHANT

Weight: Up to 5,400kg (11,905lbs)
Can reach 3m at the shoulder

3. HIPPOPOTAMUS

Weight: Up to 3,200kg (7,055lbs)
Its body can be 5.4m long

4. WHITE RHINOCEROS

Weight: Up to 2,300kg (5,071lbs)
The largest of the five rhinoceros species can be up to 4m long

5. GIRAFFE

Weight: Up to 1,932kg (4,260lbs)
A giraffe's neck can be 2.4m long

6. WALRUS

Weight: Up to 1,500kg (3,307lbs)
Its tusks can reach 1m in length

7. BLACK RHINOCEROS

Weight: Up to 1,400kg (3,086lbs)
Can be up to 1.8m at the shoulder

8. GAUR

Weight: Up to 1,300kg (2,866lbs)
The world's biggest bovid can reach 2.2m at the shoulder

9. ASIAN BUFFALO

Weight: Up to 1,200kg (2,645lbs)
It has the widest horn span of any bovid – its horns can span 2m

10. SALTWATER CROCODILE

Weight: Up to 1,000kg (2,205lbs)
The largest reptile in the world can grow to 8-10m in length

Jumbo by name, jumbo by nature

What is the single largest threat to humanity?

AMY RHYS-DAVIES, CAMBRIDGE

The human species is resourceful, adaptable, numerous and very widely dispersed around the globe. To render us entirely extinct would require a very sudden, planet-wide catastrophe. Gradual climate change of the sort that has been responsible for mass extinctions in the past wouldn't do it, because we would have time to find technological solutions that would save at least some of the species.

Global thermonuclear war, an impact from a meteorite larger than 10km, a sudden supervolcano eruption or an

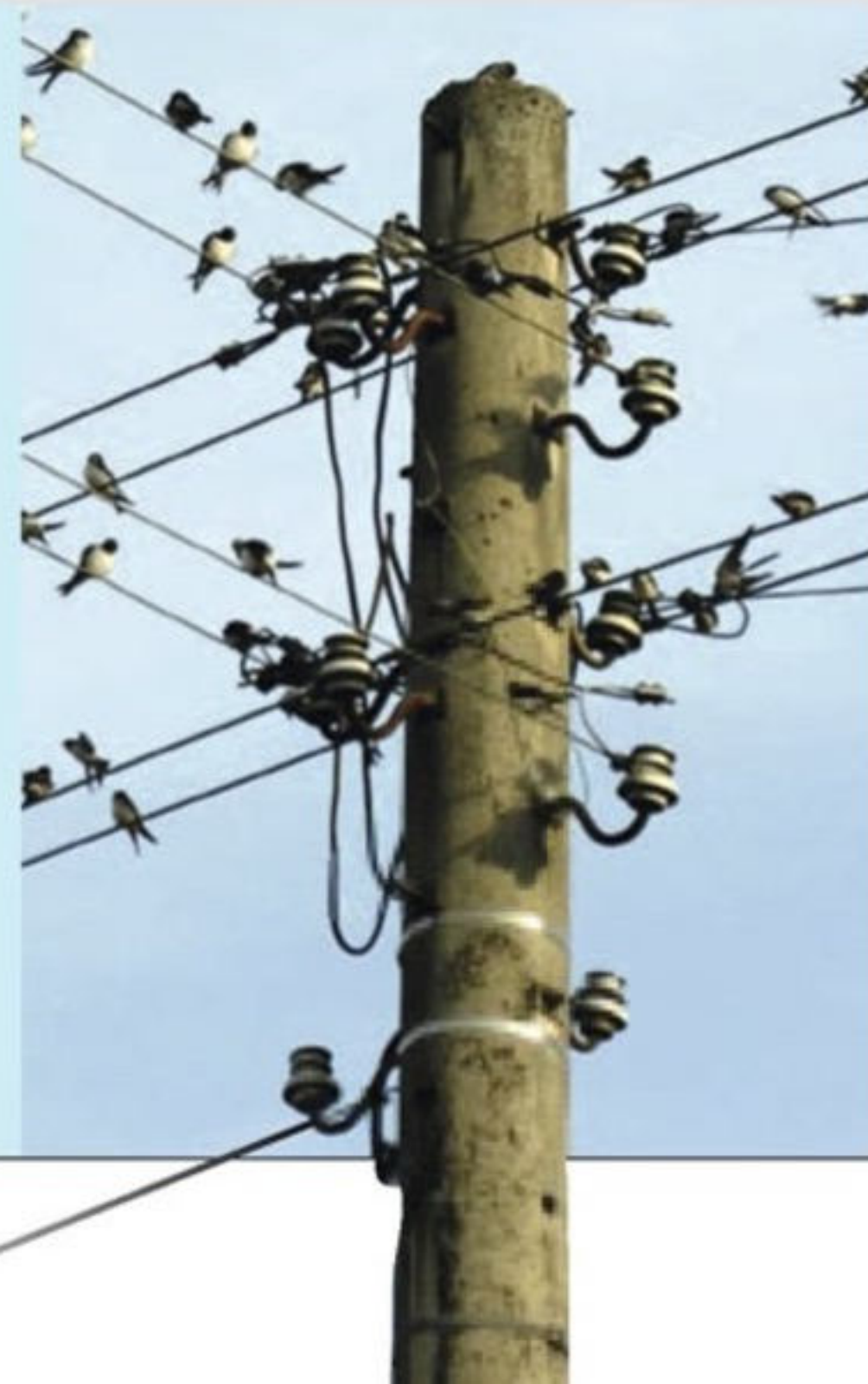
incredibly contagious and virulent disease are the only real candidates with the ability to kill enough of us, fast enough. None of them are at all likely and deciding which is the least unlikely is very difficult.

Genetic analysis has suggested that the global population may have fallen to less than 15,000 after the Toba supervolcano erupted 70,000 years ago. If a Stone Age civilisation was able to recover from a population crash like that, then the outlook for our species now is probably quite rosy. LV

Will telephone lines strung between poles soon become redundant?

STEPHEN COLLINS, BY EMAIL

Twisted-pair copper phone lines are indeed gradually giving way to fibre-optic cable. Much of this is laid underground, but on long hops through areas where it is less economical to dig into the ground, cables are strung between poles. Wooden telegraph poles are still used but, increasingly, utility towers are manufactured from tubular steel. GM



DID YOU KNOW?

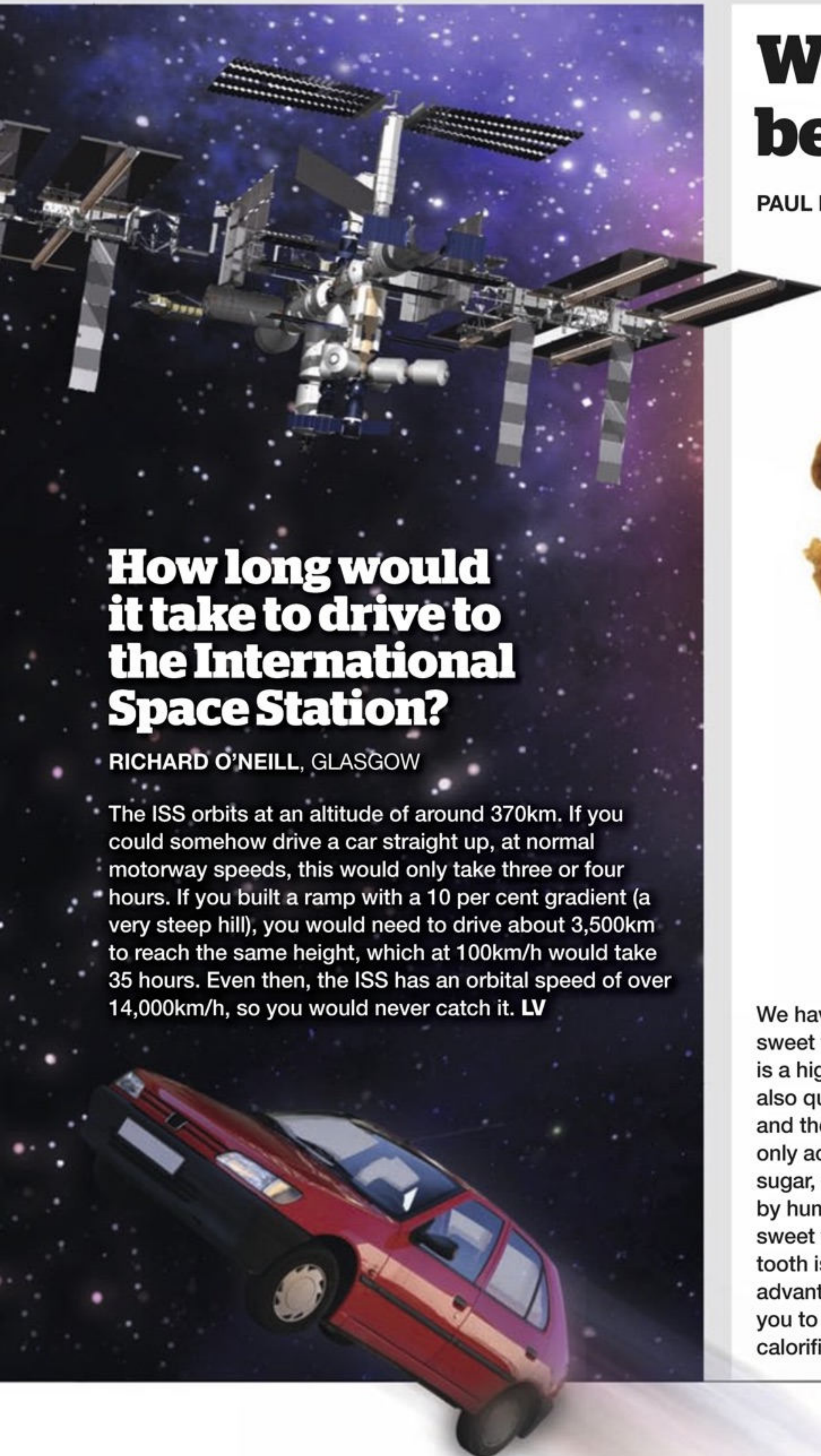
The most-streamed live broadcast to date was the marriage of Prince William and Kate Middleton on 29 April 2011, which was watched live on YouTube by 72 million people in 188 countries.



Why do your pupils dilate when you look in a mirror?

SARAH LUCAS, LEEDS

Pupils dilate for physiological reasons – because it's dark, for instance, or in response to pain – but also for psychological reasons, such as when you are sexually aroused, when you are experiencing heightened emotions or even just when you see something of interest. For most of us, our own reflection is pretty interesting (otherwise, why bother with a mirror?), so our pupils dilate slightly. **LV**



How long would it take to drive to the International Space Station?

RICHARD O'NEILL, GLASGOW

The ISS orbits at an altitude of around 370km. If you could somehow drive a car straight up, at normal motorway speeds, this would only take three or four hours. If you built a ramp with a 10 per cent gradient (a very steep hill), you would need to drive about 3,500km to reach the same height, which at 100km/h would take 35 hours. Even then, the ISS has an orbital speed of over 14,000km/h, so you would never catch it. **LV**

Why do we eat savoury before sweet at meals?

PAUL LESLIE, BY EMAIL



We have evolved a preference for sweet tastes for two reasons: sugar is a high-energy food source, and it is also quite rare in nature. Honey, fruit and the sap from certain plants are the only accessible forms of relatively pure sugar, and before they were cultivated by humans, most fruits were a lot less sweet than they are today. A sweet tooth is therefore an evolutionary advantage, because it encourages you to seek out these energy-giving calorific foodstuffs.

In the Middle Ages, most people didn't eat meals in separate courses, and fruit and meat were mixed together in lots of dishes. But refined sugar was so expensive that it was reserved for the nobility. The main meal was eaten with the servants and after it had been cleared away, the lord and lady might retire to their private rooms for a second course of luxurious sweet dishes. The word 'dessert' comes from the Old French *desservir*, meaning 'to clear the table'. **LV**

QUESTION OF THE MONTH

Could a Neanderthal be cloned?

STEVE CATER, WITHAM



Yes, in principle. In May 2010, a draft sequence of the Neanderthal genome was published in the journal *Science*, based on the analysis of fragments of DNA that had previously been recovered from 38,000-year-old bones found in Croatia. The international team, led by scientists at the Max Planck Institute in Germany, used a sequencing machine to obtain short stretches of DNA code that were then stitched together by computers. Currently, the sequence only covers around 60 percent of the entire genome. But once complete, it could be used to create an artificial genome.

However, this would be useless unless the DNA could be packaged into chromosomes inside a living cell, enabling the genes to be correctly expressed. Alternatively, the DNA of a living human cell could be altered using a nuclear transfer process, as has been done when cloning goats and cows. Finally, it might be possible to grow Neanderthal stem cells which could then be implanted into the very early stage of a human embryo. All non-Neanderthal cells would then be removed, allowing a Neanderthal baby to grow.

So it could be done, but should we do it? The result might be physically Neanderthal

but this creature would not be born into a Neanderthal society or environment and so would not be adapted to today's diseases, let alone to modern life. **SB**

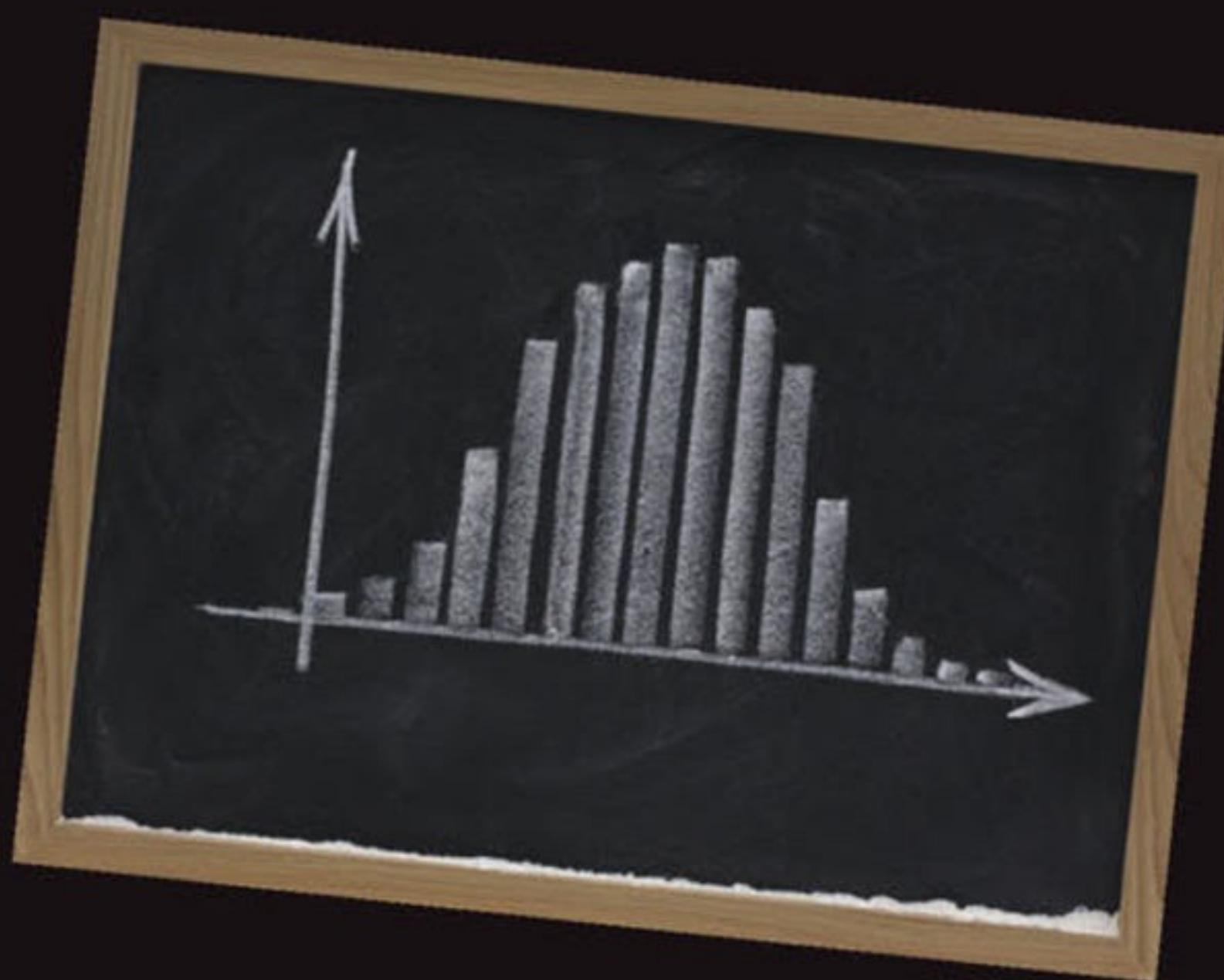


STEVE WINS A COPY OF I DIDN'T KNOW THAT VOL 1 (NATIONAL GEOGRAPHIC, £12.99)

Why is the bell curve so ubiquitous?

MARY JACKSON, LONDON

Known to statisticians as the Gaussian or Normal distribution, the bell curve is routinely used to describe everything from the outcome of dice rolls to the weights, heights and IQs of randomly selected groups of people. The reason it's so common is because many phenomena have typical or 'mean' values due to their underlying causes (such as genetics), plus random variation caused by a host of chance effects. Mathematicians have proved that if one collects lots of samples of the same phenomenon, each with their own means and scatter, the combined result will be the familiar bell-shaped spread of values. **RM**



DID YOU KNOW?

The country that makes the most cars is China, which in 2010 produced 18.3 million vehicles out of a total 77.6 million built worldwide. Chinese car sales also overtook those of the US for the first time in 2009. Japan was in second place with 9.6 million cars, while third-place USA built 7.8 million.



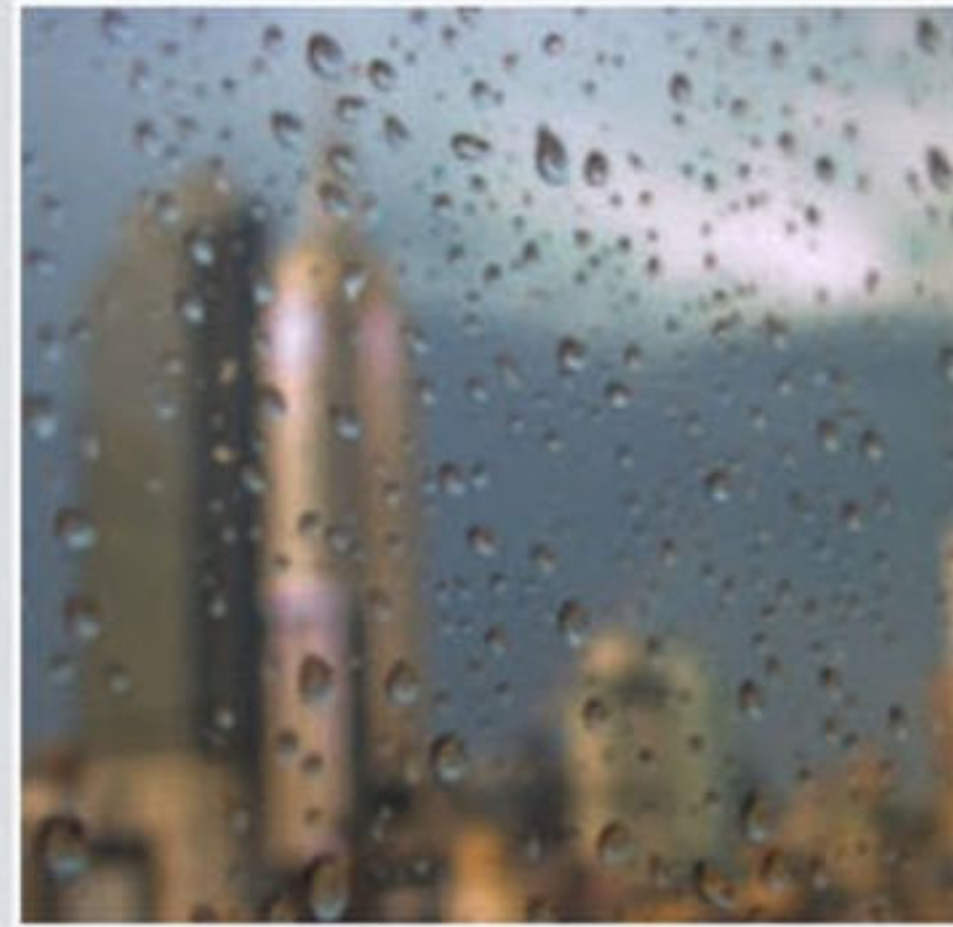
How does the Lytro camera work?

If you've ever taken a photo only to realise later that the area of interest has become a fuzzy blur in the background, help is at hand. You can now buy a revolutionary new camera that enables you to focus an image after it's been taken.

Having first developed the technology over 15 years ago, researchers at Stanford University in the US managed to cram what was once a room full of photographic equipment into one small device: the Lytro Light Field Camera. It allows you to refocus on any part of an image – either immediately, using built-in software and the camera's touchscreen, or later, using the same software on your computer. The technology is based on the camera's ability to capture something called the 'light field'. This describes the amount of

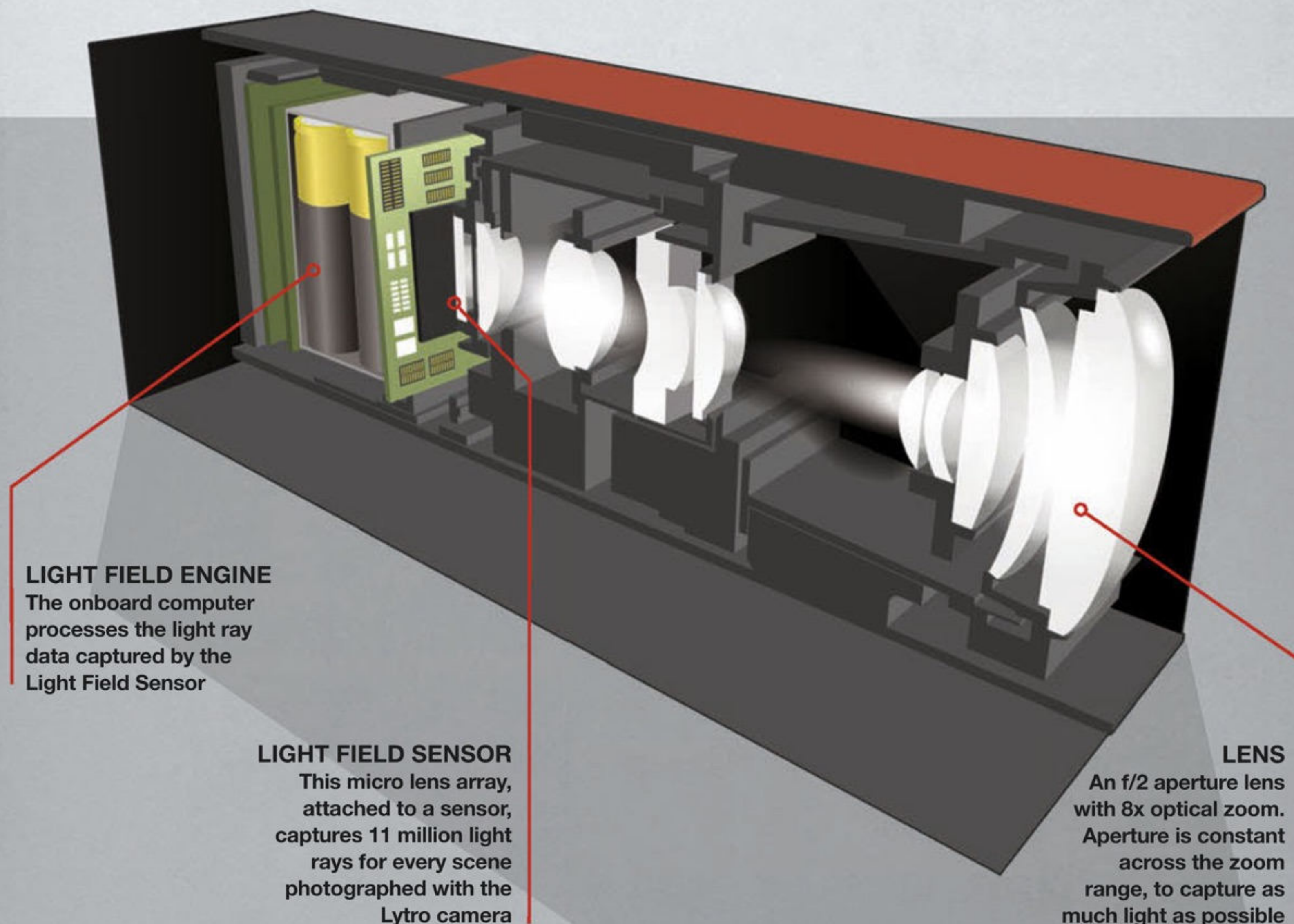


The Lytro Light Field Camera lets you refocus your images after they've been taken



light travelling in every direction through space. To record this information, the camera uses a 'light field sensor', a device that is able to record the colour, intensity and direction of 11 million rays of light. Normal digital cameras don't capture the entire light field; the directions of individual rays converge and are recorded as a single point of light.

As light enters the Lytro's main lens, it is channelled into another set of lenses and picked up by a micro-lens array at the other end. This array scatters the incoming light and the sensor is then able to describe the intensity and direction of the different light rays. The computer inside the camera, the Light Field Engine 1.0, makes it possible to refocus the images on the camera's built-in touchscreen.



LIGHT FIELD ENGINE

The onboard computer processes the light ray data captured by the Light Field Sensor

LIGHT FIELD SENSOR

This micro lens array, attached to a sensor, captures 11 million light rays for every scene photographed with the Lytro camera

LENS

An f/2 aperture lens with 8x optical zoom. Aperture is constant across the zoom range, to capture as much light as possible

How much sebum do you lose while showering?

DANIEL ROBERTS, IPAD APP

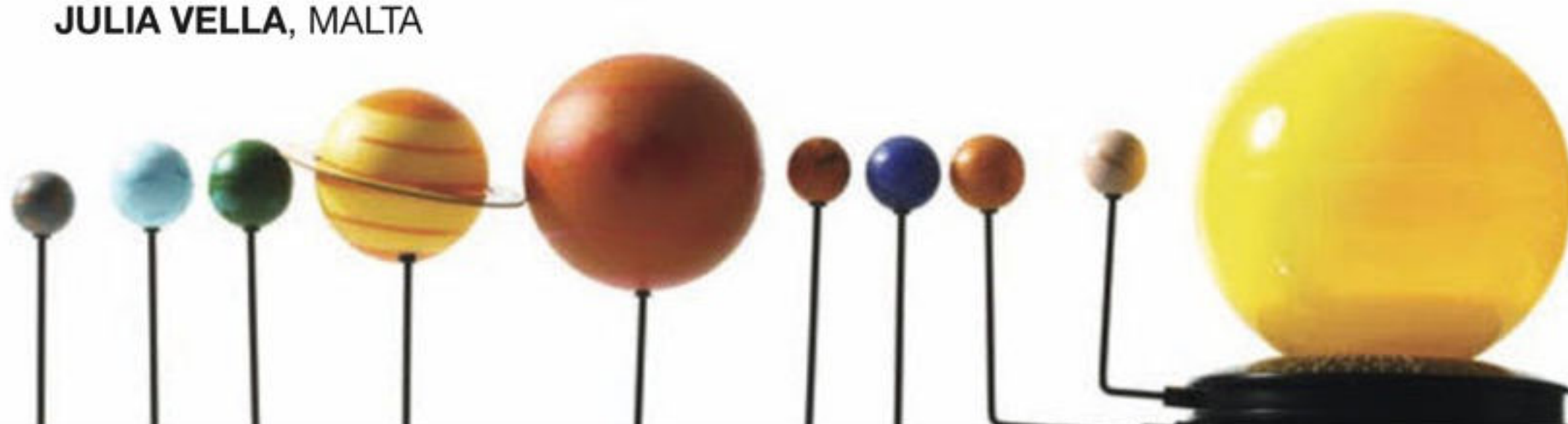
Sebum is a mixture of oils and waxes that are secreted by your skin to help keep it waterproof, prevent sweat from dripping off and limit the growth of bacteria. You don't, however, need a huge amount of it to do this: even on the oiliest parts of the body, such as the head, most adults only produce about 0.03mg of sebum per square centimetre of skin, per hour. If you are a teenager with acne, that figure will be about three times as high.

Your skin has a total surface area of about 1.8m². If we assume that the average sebum production over your entire body is about half the value for the head, that gives us a total production of about 6,500mg in a 24-hour period.

Depending on how hot your shower is, and how vigorously you rub, you might wash off half of that. That equates to about 3g (roughly 4ml) for most of us, and 9 or 10 grammes for teenagers. **LV**

Why do celestial bodies have the same shape?

JULIA VELLA, MALTA



Large celestial bodies such as planets and stars are spherical. This is because two forces, one of them gravity, are balancing each other. In stars, the gravity, which tries to compress the star, is balanced by the thermal pressure acting outwards. In planets, the gravity is balanced by matter's natural resistance to compression. In both cases, the two forces are in equilibrium and so the object takes on the most compact shape possible – a sphere. **AG**

Skywatching with astronomy gurus Heather Couper and Nigel Henbest

11pm, 15/16 June 2012



What can I see in June?

● **3 and 4 June, south, from 11pm**

The Full Moon passes close to Antares, the brightest star in Scorpius. This red giant is a monster: it shines 10,000 times brighter than the Sun, and if placed in the Solar System, it would reach to the asteroid belt. Scorpius itself is a sensational constellation, but you'd to be as far south as the Mediterranean to see the pincered beast in all its glory.

● **6 June, northeast, from 4.45am**

You'll be able to catch the last hour of a transit of the planet Venus across the Sun, which will be very low down in the northeast. **NEVER** look directly at the Sun – either use solar eclipse goggles, or project its image through a telescope or binoculars onto a piece of white card.

Watch *The Sky At Night* on BBC One. Check radiotimes.com for details

BBC
one

The planets Saturn and Mars live up the constellations Virgo and Leo this month. Look out also for red giant stars Arcturus and Antares (whose name means 'rival of Mars')



Can honey really fight infections?

SARA BIDDULPH, LEICESTER

Yes. Honey has been used to treat wounds for thousands of years and is still used today. The best known antibacterial and antifungal honey is manuka honey, made by bees feeding on manuka, the tea tree bush *Leptospermum scoparium*, which grows in New Zealand and Australia. It has been reported to inhibit more than 80 species of bacterium, and recent research is investigating how it works.

Bacteria that live on your skin, such as *Streptococcus pyogenes*, are normally harmless but sometimes prevent wounds from healing by clumping together to build a 'biofilm'. This film then prevents drugs such as antibiotics from entering the wound. Recent research shows that manuka honey prevents these bacteria from sticking to the wound tissue and can even destroy the biofilms once they have formed. No instances of honey-resistant bacteria have been reported and applying antibacterial agents directly to the skin to clear bacteria from wounds is far preferable to using systemic antibiotics. So honey may be a very useful treatment. **SB**

Is it possible to create any kind of perpetual motion device?

ERICA JUSTICE WILLIAMS, FACEBOOK

Strictly speaking, such devices violate the laws of physics, as they need to be supplied with energy from some external source to make up for the energy losses resulting from their action, such as frictional heat. But in practice, there are trillions of effectively perpetual motion devices throughout space: they're called stars. For most people, billions of years of nuclear fusion-powered turbulence would pass for perpetual motion. **RM**

What was there before the Big Bang?

FERGAL O'BRIEN, DUBLIN

Until recently, scientists argued that because time was itself created in the Big Bang, it simply made no sense to talk about what came 'before'. But now some theoretical physicists working on combining quantum theory and Einstein's Theory of General Relativity are having a change of heart. Prof Martin Bojowald of Penn State University has found hints that there was indeed a universe before ours, which underwent some kind of 'bounce' and re-emerged as our own expanding Universe. Whether this claim will ever be supported by observational evidence is unclear, but at least it's no longer frowned upon even to ask such questions. **RM**

Why do you get white noise when you record sound?

CHARLOTTE HEPPLEWHITE, BASINGSTOKE

The noise is partly electromagnetic and partly acoustic. Air molecules are constantly moving around in the room and their energy is picked up as unwanted sound. Audio systems do not discriminate as well as our ears, so the ambient noise is more apparent in the recording.

Recording equipment is also susceptible to electronic interference from nearby power sources, radio transmissions, mobile phones and even the cosmic microwave background radiation. Audio cables have a metallic sheath to block out this electromagnetic interference. **GM**

DID YOU KNOW?

The six-lane Qingdao-Haiwan road bridge in China's Shangdong province is the world's longest bridge over water. The earthquake- and typhoon-proof bridge, which opened in 2011, is 42.5km (26.4 miles) long, and was built using 450,000 tonnes of steel.



NEXTMONTH

Will teleportation ever become a reality?

Do you burn more calories during deep thought?

How close are we to finding life on another planet?

Is the brain of a genius heavier than an average brain?

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The Guide

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WARNING!
Don't look at the Sun without
suitable eye protection

TRANSIT OF VENUS

It's your last chance to see it this century – *Horizon* looks at the story behind the spectacle

When Venus slipped silently between the Earth and the Sun in 1769, the rare but highly anticipated event created a buzz of excitement around the world. Astronomers hoped that measuring the transit of Venus – observed for the first time just a century earlier – would help them calculate the Astronomical Unit (AU), the distance from the Earth to the Sun, and from that fathom the true scale of our Solar System.

This June, the transit of Venus will happen again – at around 5.15am on the 6th, for those of us in the UK. With suitable eye protection, Venus will be visible as a small black dot slowly crossing the face of the Sun. Transits occur in pairs, eight years apart, which are then separated by gaps of 121.5 and 105.5 years. The first transit in the current pair took place in 2004; miss this one, and there won't be another till 2117.

Back in the 18th century, men of science travelled far and wide to secure the best viewing positions. Captain Cook endured a lengthy, dangerous, scurvy-ridden trip to Tahiti to observe it, while French astronomer Guillaume Le Gentil spent so long looking for it, he was declared dead. Closer to home, King George III had Kew Observatory specially built for it. "There was a real sense of international collaboration," says Marek Kukula, Public Astronomer at the Royal Observatory Greenwich. "Suddenly lots of people

started to get really excited about astronomy. It was like an 18th century version of the Brian Cox effect." Despite their best efforts, though, 18th century astronomers managed only a rough estimate of the AU, and it wasn't until the advent of photography in the 19th century that the exact details were nailed.

Cook's story is retold by solar physicist Lucie Green in a *Horizon Special* celebrating the transit. Oceanographer Helen Czerski explains how data from the Venus Express space probe hints that the planet may unexpectedly possess active volcanoes, while biologist Liz Bonnin finds out how Venus is transforming our understanding of our own planet, including dramatic new evidence for life in the upper surface of clouds.

The transit of Venus still has scientific significance. By looking for dips in light from distant stars, transits can be used to look for new planets and even to peek inside their atmospheres. If you want to help, you can download a smartphone app and participate in a global experiment measuring the size of the Solar System. Just don't forget to set the alarm!

BBC TWO The Transit Of Venus: A *Horizon Special* is on BBC Two at 9pm on 5 June. To find out where and when to see the transit, and to download the app, visit www.transitofvenus.org

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The Review Squad

Jamie Carter

Curious about what Windows 8 has in store? Well you can stop wondering, because we got gadget-mad Jamie to find out. He reveals all on p88.



Daniel Bennett

Reviews editor Dan has been going downhill fast this month... on a mountain bike, that is, as he tested out the latest all-action, strap-on camcorders.



Helen Pilcher

Science journalist Helen is a neuroscientist by training, but this month we had her looking skywards to bring us a preview of the transit of Venus on 6 June.



Jane Douglas

A section editor at Gamespot UK, Jane puts the latest games through their paces as well as asking, just where are all the female lead characters?



Jheni Osman

Former *Focus* editor Jheni is an in-demand science author these days, but somehow she still finds time to put together our monthly events listings.



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TAPPING INTO THE SMARTPHONE

Sony's latest can 'talk' to other gadgets with its tag technology



What's so special about this smartphone?

Apart from its transparent midriff, the Sony Xperia S looks like any other rectangular, black smartphone. But it includes one innovation that sets it apart from the herd: as well as an NFC chip inside the phone, it has programmable NFC chips called Smart Tags that the phone can 'talk' to.

What's NFC?

It stands for Near-Field Communication. The NFC chip in the phone generates a small magnetic field. This induces a current in any other NFC circuit that comes close enough to it, like one of the Smart Tags, providing it with enough electricity to broadcast a weak signal. The phone recognises this and acts out whatever instructions have been attached to that chip.

What are Smart Tags?

The phone comes with four of them. They're small, poker chip-sized, coloured buttons that can be associated with a set of commands. When one is tapped on the back of the phone, the NFC chip in the handset will recognise it and allow you to link a set of

functions to that tag. So you could, for example, teach the phone to switch to loud mode, turn on its Bluetooth and pair with your car's stereo system after it comes into contact with a specific tag.

What's the point?

NFC chips are becoming ubiquitous in smartphones, but not much else. While we wait for manufacturers to add them to speakers, PCs and other gadgets we might want to connect to, these Smart Tags provide a simple go-between. We stuck ours to a Bluetooth speaker, so that we could pair our phone to it simply by tapping them together.

What else can it do?

If you've got a Wi-Fi-enabled TV, you can send video, music or photos to your screen wirelessly, or use an HDMI cable to view the internet. On top of this, it records video in 1080p HD. Being NFC-enabled, you'll also be able to use the phone to make payments with co-operating banks and retailers by simply tapping your phone at the check-out.

Sony Xperia S

Price: £399

www.sonymobile.com

Objects of desire

Specs appeal

Whether you enjoy the effect of 3D films or not, it still feels like a blow to your dignity to have to wear a pair of shades that Ali G would be proud of. Much like the far smaller Nintendo 3DS, this 55-inch TV uses a lenticular lens to create 3D images without the need for glasses. It sends a slightly different picture to each eye, creating the illusion of depth. We've seen the effect for ourselves, and it definitely works – though it tends to fade in and out as you move around the room.

Toshiba ZL2

Price: £6,999

www.toshiba.co.uk



Phone operator

This free app enables you to control every aspect of your PC using your smartphone's touchscreen display. Via a wireless network connection you can turn your phone into a customisable game controller, handle your social networks, play your music and more besides. The docking keyboard seen here can be bought as an extra, but is not required to use the app.

Roccat Power-Grid

Price: Free, keyboard price TBC

www.power-grid.roccat.org



Electric dreams

Battery-powered cars are a great alternative to gas-guzzlers, as long as you never want to drive far from home. Vauxhall's new hybrid car offers an elegant solution for those times when you need to stray further than your daily commute. Electricity spins the wheels at all times: its battery provides a maximum range of 80km, but when it runs low, a petrol-powered generator provides more juice to carry you a further 500km.

Vauxhall Ampera

Price: TBC

www.vauxhall-ampera.co.uk

Drawn out

Built for designers, this traditional-looking stylus and tablet is also touch-sensitive. While you can draw with the pen device, the tablet reads touch as a separate input. This means you can zoom in and out, move the image around or rotate it, all with simple gestures.

Wacom Intuos 5 Touch

Price: £199.99-£429.99, depending on size
www.wacom.eu



One-wheeler

What are circus clowns going to do now that there's a unicycle that balances itself? A series of accelerometers and gyroscopes keep the electric-powered SBU V3 (Self Balancing Unicycle) level as you scoot around. You steer by shifting your weight from side to side – after 20-30 minutes, the sensors learn the motion. There's even a failsafe that shuts off the motor if it thinks you're about to make an undignified dismount – which is handy, given that it reaches a top speed of 24km/h.

SBU V3

Price: \$1,795

<http://focusdesigns.com/sbu3>

Ball games

This robotic ball enables you to play virtual games with your smartphone. With an accompanying Android and iOS app you can move it around with a tilt, touch or swing of your phone. For instance, the game Sphero Golf turns your phone into a virtual club. Take a swing and your smartphone's accelerometers send instructions to the ball, telling it how quickly and how far to roll.

Sphero

Price: \$129.99 plus P&P

www.gosphero.com



WINDOWS 8

Jamie Carter tests the operating system that promises to radically change the way we use PCs, tablets and phones

What's new?

Microsoft is breaking Windows. In fact there's not a 'window', as we think of them now, in sight. The new operating system from the PC giant radically alters how we interact with computers to bring new tablets, ultrabooks and smartphones into one big Windows family.

What does it look like?

After you fire up the PC, a screensaver must be swiped upwards. Although it's possible to do this with a mouse or by pressing the spacebar, it's an instant reminder that Windows 8 has been designed to be operated with your fingers.

Behind the screensaver, the brand new home screen, codenamed 'Metro', looks great. The tiled screen of square and rectangular icons are as neatly arranged as they are dynamic. Brightly toned blocks act as live icons, that cycle through the content inside. For example, the tile for photos is a slideshow of your pictures; Finance shows real-time share prices, while Weather displays the local forecast. Best of all, unlike so many products these days, it doesn't remotely resemble anything previously designed by Apple.

What new features are there?

Windows 8 sees the arrival of Windows Store, a software market much like the app stores on an iPhone or Android smartphone. Just like on your phone, once downloaded they appear on the Metro home screen – rather than being tucked away in your Start bar. Software isn't just geared towards productivity or games any more, either – early apps include *The Telegraph* and *USA Today*.

There are also several bundled apps, such as SkyDrive (cloud storage), Remote Desktop, and Xbox Companion, which controls and swaps games with an Xbox 360 and lets you stream video from your PC to your console.

All of your settings and preferences are stored in the cloud and attached to your unique Windows Live ID. So when you sign in, any device you use will feel like it's yours, and with cloud storage you can access your vital files from anywhere. With services like iCloud and Dropbox this is already possible, of course, but the difference – and it's an important one – is that Windows 8 makes the whole process truly effortless.

How easy is it to use?

Overall, it's sharp, quick and simple, and it makes complete sense for use on a tablet PC or smartphone. But on a desktop PC, having to use the mouse or the arrow keys to move from one block to another, and scroll over several pages, is slow and frustrating.

Windows 8 kills the 'Start' button too, which will be problematic for those not keen on big changes in how their PC works. Apps don't even have a red 'x' to close them. The whole system will certainly take a few weeks to acclimatise to.

What if I liked Windows the way it was before?

If this all seems like too much change, you'll be happy to know that classic Windows *has* actually survived to some extent. You can switch between Metro and the old-fashioned desktop, but there's no integration between the two.

Should I upgrade now?

It depends on how you use your PC. Overall, Windows 8 is a mobile-friendly operating system we're all likely to use one day. But, as it stands at the moment, it's too tablet-focused. Office workers, who are surely the majority of Windows users, often aren't permitted to stream videos, and certainly not to sync with cloud storage. So why should they be trapped in an interface that's heavily based around doing these things?

Despite these concerns, Windows 8 is a bold step towards what computing *should* be like. Intuitive and simple, you won't need someone standing over your shoulder to tell you how to use it. When it's released on the first tablet later this year, we're sure it'll be a big success, but it needs some work before its potential is fully realised on the PC.





THREE WAYS WINDOWS 8 WILL CHANGE COMPUTING

Broken windows

The browsing experience that gave Windows its name makes its exit, replaced by a touch-centric interface called Metro – a screen of tiles for photos, software, documents and apps. A massive break with tradition, it's simple to use and ideal for an index finger, but slow to use with a cursor. There's no Start button, either.

Head in the cloud

Windows 8 puts everything in the cloud. With personal storage – called SkyDrive – gifted to every user, Windows 8 lets you log into any online computer in the world to access your desktop, settings, applications, documents, photos, movies... even your own avatar. Unlike Google Chrome, which requires a constant internet connection, Windows 8 syncs with the cloud as and when it can.

Access all areas

Files, photos, movies and documents stored in the cloud will also be accessible from Windows phones, Xbox 360s or any other Windows 8 device. So not only will these operating systems look similar, but they'll have access to all your content and settings, unifying all your gadgets in one big, happy Windows family.

Action cams

Going biking, skiing or diving? These camcorders record high-octane action while handling knocks, bumps and spills. **Daniel Bennett** turns stuntman

Why would I want one?

As any designated cameraman or woman would attest, camcorders have an annoying tendency to get in the way of you and the moment you're supposed to be enjoying. Having to frame a shot, hold the camera steady and take care of hundreds of pounds' worth of equipment can be distracting. It's certainly not something you'd want to be doing while hurtling down the side of a mountain on a bike. These cameras, on the other hand, can attach to pretty much anything, leaving your hands and attention free. They'll go anywhere, including underwater, and endure a lot of punishment, yet still come up with the goods so you can relive the day's thrills and spills later on.

Why can't I just use a normal camcorder?

If you try to capture fast-moving action with a standard camera or camcorder, the end result will suffer from distortion: the images tend to be skewed, smeared, strangely exposed or warped. This is because camcorders and cameras record images piece by piece, rather than capturing the entire frame in one go. Typically this technique provides richer images, as each portion of the image can be recorded with more detail. But fast movement means that one part of the image is captured split seconds after another – resulting in strange glitches. The cameras on test here use various methods to avoid this, giving you high-fidelity, fast-moving footage.

Are there any drawbacks?

If you want to film your holiday or your kid's first steps then these cameras won't cut it. Built for outdoor, active use, they're made to be strapped onto something – your head or a crossbar – and forgotten about. This means they've been stripped of all unnecessary features to make them as light and as small as possible. Most don't even have screens. There's only one focus setting, no physical zoom and their image sensors all seem to suffer a little in low light. And since they'll mostly be recording the sound of the wind blowing past, their microphones aren't the best. These models are strictly for action-packed fun – your normal camcorder is for everything else.

How we tested them

Video quality

Visual fidelity is king. Video should be free from any distortion and produce good results whatever the light conditions. The best cameras are those that will pick up fine detail at even the highest speeds.

Ease of use

The camera should be easy to use on the fly. It should be quick and simple to start and stop recording, and hassle-free to attach to a helmet or anything else to hand.

Features

To reduce their size and weight these camcorders have been pared back to the bare essentials. Any extra features like a screen, GPS recording or Bluetooth are a boon, and worth spending extra to get.

Build

The cameras need to be toughened to deal with the knocks they'll inevitably take. Waterproofing or shockproof housing is vital for this kind of camcorder.

MUVI
HD PRO
£249.99

**GOPRO
HD HERO 2**
£299.99



**ATC MINI
ACTION
CAMERA**
£119.99



CONTOUR+
£379.99





GoPro HD Hero 2

£299.99 www.gopro.com



The footage from GoPro models is of such high standard that they're often used by TV film crews as helmet cams. Of the four cameras, the video captured was the best – we've never seen anything like it. Strapped to a bike and thrown over hilly terrain, it recorded every bump, dip and wobble without any distortion. Faster movement in a car didn't phase it, either. Apart from the mundane nature of what was in front of the camera, which was our fault, the video had a filmic quality to it.

The camera itself isn't hardened, but it comes in a waterproof case that can endure some considerable abuse, which is fortunate since we dropped it a couple of times trying to find the best way to strap it on.



Set-up was a little tricky. In fact, we actually had to resort to reading the instruction manual to figure out how the unmarked buttons worked and how to affix the cam securely.

The basic pack is precisely that: basic. Extra features like an attachable screen or a Wi-Fi remote, have to be bought separately. Without a screen, getting the camera pointing in the right direction is likely to take several attempts.



Resolution: 1080p
Stills: 11MP
Connectivity: USB, SD card
Weight: 190g

Video quality: ●●●●●
Ease of use: ●●●●○
Features: ●●●●○
Build: ●●●●○
Overall: 15/20

Contour+

£379.99 www.contour.com



Although this looks like the simplest camera in the group, it actually packs the most tricks. There's a GPS tracker that records your route, speed and elevation as you film. It also connects via Bluetooth to an iPhone or Android smartphone, turning your phone's screen into a viewfinder and letting you adjust the exposure, saving you from endless failed takes.

The footage is nearly flawless – the only time it faltered was when we dipped into dimly lit wooded areas, and even then it still captured small details at speed, such as the dirt kicked up by a fellow cyclist. The Contour's streamlined shape also made it the least conspicuous and most comfortable to wear.



It took a little while before we could get a GPS lock, which could be a pain as it might mean waiting for it every time you set off. If you don't have a smartphone, it uses a red laser pointer by the lens to show you which way the camera is pointing, but we found this to be almost invisible in daylight.

Also, watersports fans take note: to take it fully underwater, a waterproof housing is required, and this is not yet available.

Video quality: ●●●●●
Ease of use: ●●●●○
Features: ●●●●○
Build: ●●●●○
Overall: 17/20



Resolution: 1080p
Stills: 5MP
Connectivity: USB, Mini HDMI, Bluetooth, Micro SD card
Weight: 160g
Extras: GPS, Bluetooth



ATC Mini Action Camera

£119.99 uk.oregonscientific.com



At £100 cheaper than the others on test, the ATC is the economy option of the group. Compared with the other cameras its rubberised body is indicative of its price tag, but it does lend it a punchbag feel: it'll take knocks and scrapes without showing any signs of damage. It's waterproof too, with no extra housing required, and its big, easy-to-use buttons are simple to get to grips with even if you're underwater or wearing gloves.

All these cameras are for big kids, but this one is clearly aimed at a younger user, and it's perfect for that. The video is smooth and mostly glitch-free, making it a good starting point for an amateur filmmaker.



The video seemed a little grainy, especially in badly lit scenes. It doesn't record in full 1080p, but more importantly the camera's field of view is much narrower than the others on test – it won't capture a significant portion of what you see. When we got to higher speeds in the car, the images started to warp along the top of the picture, so this wouldn't be the camera to pick for recording a track day.



Resolution: 720p
Stills: 1.3MP
Connectivity: TV-out, mini-USB, Micro SD card
Weight: 120g

Video quality: ●●●●●
Ease of use: ●●●●●
Features: ●●●●●
Build: ●●●●●
Overall: 12/20

Muvi HD PRO

£249.99 www.veho-uk.com



After the trial and error involved in setting up the previous three screenless camcorders, the Muvi's LCD screen was a welcome sight. It's just as compact as the GoPro but requires an extra case, which is not supplied, to make it toughened and waterproof.

The footage was bright and smooth – in terms of video quality there was little obvious difference between this and the Contour+ or GoPro. The screen means it can double as an impromptu camcorder, and it was also the only camera of the four we were tempted to take still photos with. For such a small device these came out surprisingly well, making it the best all-rounder here.



Closer inspection revealed that the video was less crisp than some, that the colours weren't as lifelike and that darker areas lost their detail. The field of vision was very slightly smaller than the GoPro and Contour+ too.

Without the extra waterproof case the camera just doesn't feel as tough as the others. And although it coped with a drop from our sieve-like hands, we're not sure how many such impacts it would survive.

Video quality: ●●●●●
Ease of use: ●●●●●
Features: ●●●●●
Build: ●●●●●
Overall: 14/20



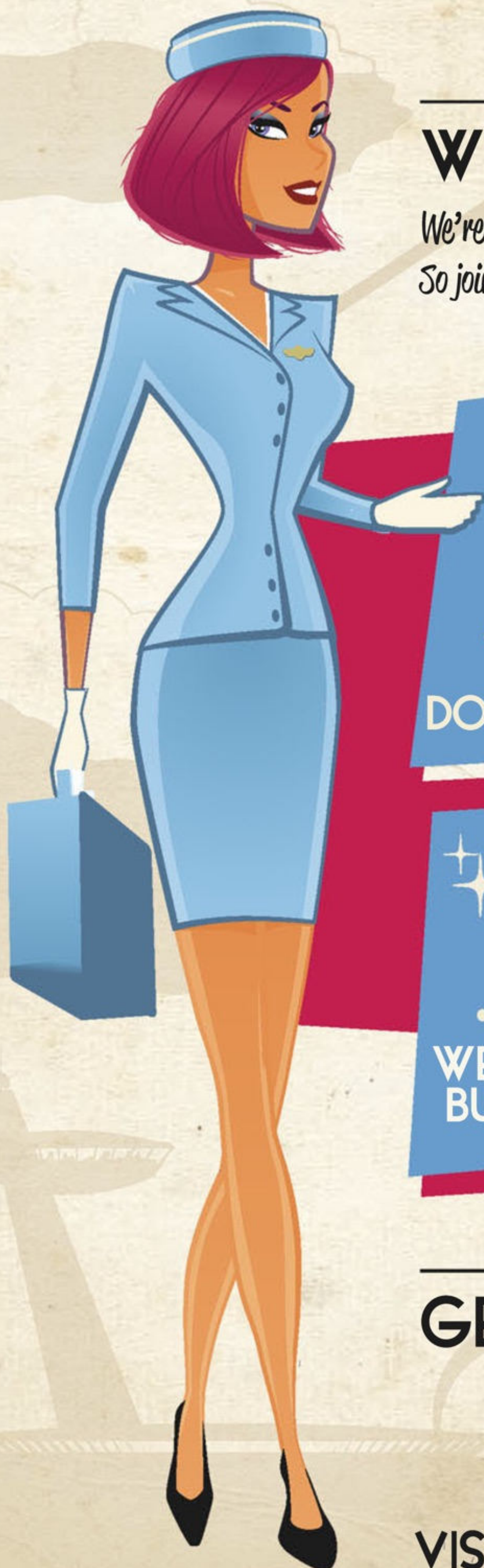
Resolution: 1080p
Stills: 8MP
Connectivity: Micro SD card, mini HDMI out, USB, A/V out
Weight: 81g

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It's been years since I've slid down a grassy slope, rolled over and pretended to open fire on a

robot. But for the first time since I was 13 (alright, 23), I was an action hero for a day as we tried to film a short sci-fi movie using the video camera on a smartphone.

All the footage, all the special effects and all the colour grading would be done in-phone, using only apps and attachments. And I have to say, the results weren't bad at all. In fact, if I were in the camcorder industry, I'd be worried.

To be fair, getting good shots took quite a bit of patience. There are a few tips to



Movies shot on your phone can look rather impressive

shooting good pictures, which are even more important when filming. First, you need to turn autoexposure and autofocus off, for which you'll need an app like Filmic Pro. You'll also need a better lens – an iPhone-compatible telephoto lens gives a depth of focus that James Cameron would be proud of.

Oh, and regardless of whether you're using a phone or one of Cameron's 3D stereoscopic beasts, the rule is the same – shoot the heck out of a scene, from as many angles as you can. You'll thank me when it comes to the edit.

There are a number of post-production apps, like Action Movie FX made by director JJ Abrams' production company, that will add missile strikes or tornadoes to your scene, as well as others like iMovie that add more subtle effects.

I'm wondering if, when my old camcorder gives up the ghost, I'll bother getting a new, high-def, flash memory model. Perhaps I'll just use the one I have with me all the time – which also makes phone calls, and which can add explosions to my holiday videos.

Spencer Kelly is the presenter of the BBC's technology show *Click*

How to...

TAKE BETTER PHOTOS WITH A SMARTPHONE

Your phone might have an eight-megapixel camera, but are you getting the most out of it? Here are some simple tips to improve your photography skills



Get the basics right

Clean the lens: a handset's camera gathers a lot of dust and grime sitting in a pocket, and a clean lens will let more light through to the camera sensor. Phone cameras also struggle with low light, so make sure whatever light source you do have is behind you, illuminating your subject. Finally, compose your photos properly: divide the screen into three vertical lines and place the subject on one of them.

Know your smartphone's limits

If you're tempted to zoom in on a subject, don't! Smartphone cameras only offer digital zoom, which simply stretches the image and pixelates the photo. Instead, get as close as you can before snapping your shot. The phone's weakness in low light is likely to make you want to use the flash, but this can often bleach photos. Take two shots if you can, one with and one without flash, just in case.

Download Instagram and other apps

There's one thing a phone can do that a camera can't – use apps. Instagram (iPhone) or FxCamera (Android) will provide all kinds of fun filters and effects. For instance, with Instagram you can apply a vintage filter before seamlessly sharing the photo in the app or via Facebook or Twitter. If you want to tweak a photo, iPhoto (iOS) or Adobe Photoshop Express (Android) will let you edit it with your fingers.

Tech Doc's App Prescription



Inside The World Of Dinosaurs iPad £9.99

Narrated by Stephen Fry, this is clearly an app for children: the information it contains is solid enough, but any app that promises dino fights probably isn't hoping to be cited in academic literature. The fights are less exciting than they sound, but the 3D models, profiles and timelines will keep older kids engrossed.



Khan Academy iPhone, iPad Free

Khan Academy's mission is to provide a free education to anyone, anywhere. This app presents over 2,700 of the Academy's accessible videos in an easy-to-navigate interface. The low-key, doodling style means each video can be a great primer in any topic you want to get up on.

No girls allowed?



So rare are high-profile female game protagonists that, 16 years after the creation of Lara Croft, you

could squeeze her and the other notable few into a lift, while her male counterparts number enough to comfortably invade and occupy France.

Take the latest instalment in stealthy stab-'em-up series *Assassin's Creed*, set during the American Revolution. Its hero, Connor, is the third of the series' historical assassins – all men so far, despite public cries for a female lead. The game's creative director, Alex Hutchinson, says that though there's lots of fan interest in a lady assassin, one just wasn't plausible for the Revolutionary War. Because the revolution was all dudes in powdered wigs, players "would stop believing" in her.



Assassin's Creed III hero Connor: definitely not a girl

Setting aside for one moment the game's rather liberal interpretation of history and the role played by women in it, this still seems like a tactful dodge for a more commercial rationale. Namely, publishers believe more gamers want to play as men than as women.

They might even be right. By the last count, less than a fifth of *Mass Effect* players chose to play as a female version of the main character. Audience focus-testing seemingly steers Activision well clear of games with women in lead roles. And in terms of lead characters, the sales chart is a boys club, though not without exceptions – see 2010's *Final Fantasy XIII* and its heroine Lightning.

Still, however many fans clamour for a female assassin, the figures show they are probably happiest with a hero. Which makes male characters the safe bet, even if this fails to give us an eclectic, inclusive array of unique, iconic leads.

Jane Douglas is section editor of GameSpot UK

The campsite's "no evil snake-tailed monsters" rule didn't seem to be working

DIABLO III

PC, Mac
Blizzard, £39.99

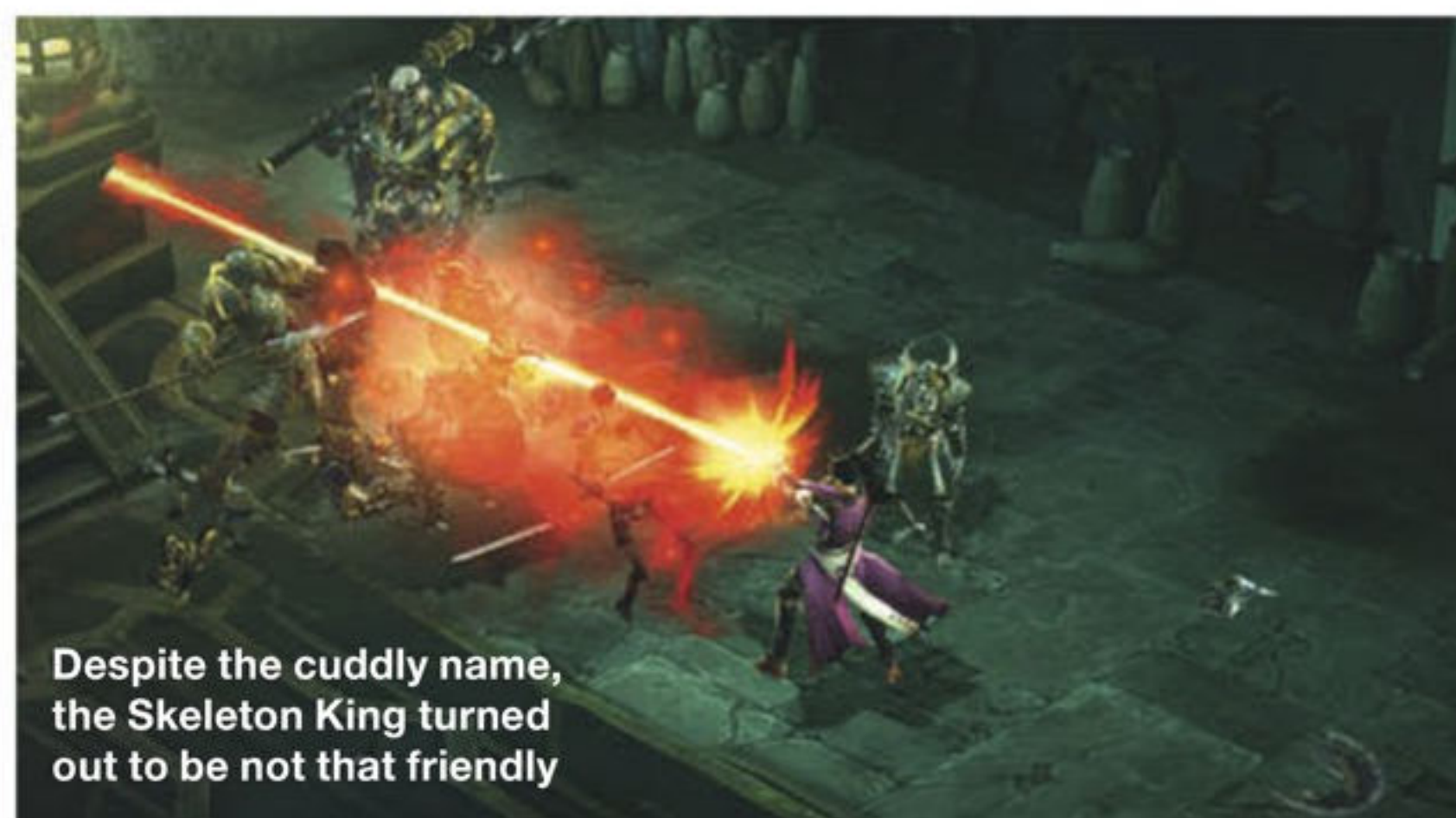
Few games arrive to anticipation as keen and as long-running as *Diablo III*. Such is the passion commanded by 2000's *Diablo II*, a role-playing 'dungeon crawler' still played by many fans 12 years after its release.

Those new to the series (and maybe to the genre) should expect to steer an archetypal hero, such as a barbarian or a wizard, through richly detailed fantasy environments, clobbering monsters and seizing treasure. Seasoned gamers familiar with its predecessor should look forward to a pleasing mix of the new and the cosily familiar.

The game's traditional, top-down perspective will be immediately recognisable to fans, though the detailed visuals have clearly benefited from a decade's worth of progress. The series' main cornerstones of

action and character progression have been upgraded too, with cleverly evolved takes on hero skills and loot gathering. But for all the game's upgrades, there's a pleasingly old-fashioned feel to proceedings. Blizzard's magic trick is evoking this without making a fusty, dated game mired in its own nostalgia.

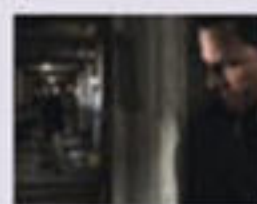
In fact, far from being stuck in the past, the game pioneers a new system whose impact may well ripple through to the rest of the gaming industry. Players will be able to sell items to each other via an in-game auction house. The game-changer is that these swords and staves can be bought and sold with real-world cash as well as digital gold, with Blizzard taking a cut. So for once, playing on your PC all day could actually earn you some money.



Despite the cuddly name, the Skeleton King turned out to be not that friendly

ALSO OUT

MAX PAYNE 3



X360, PC, PS3
Rockstar
£39.99

Nine years after PC classic *Max Payne 2*, its titular hard-boiled hero returns with a new look in a new city. Leaving wintry New York behind, shaven-headed Payne turns his hand to private protection for a rich family in sunny Sao Paulo. The new action revives the preceding games' slow-motion, guns-blazing dives and dodges, adding in modern elements such as a cover system and interactive set-piece spectacles.

DRAGON'S DOGMA



X360, PS3
Capcom
£39.99

Into the recently crowded field of fantasy role-playing games wades a contender with an intriguing online gimmick. In *Dragon's Dogma*, your character is accompanied into battle by a party of three customisable companions, with your main 'pawn' your own creation but the other two recruited from friends' games. It's a taste of intersecting game worlds in an otherwise single-player sword 'n' sorcery adventure.

Bill Thompson

An eBay for car rentals



The UK's 'internet economy' is worth over £100 billion a year, according to research by the US-based Boston Consulting Group. Over three-fifths of us buy things online, putting the country ahead of most others when it comes to internet shopping. Our broadband, while maybe not the fastest, is widely available, and that

seems to be the key to online engagement even if we can't all get HD video on demand. And the way we engage with companies online is beginning to shape the way we do business offline, too.

The real power of the internet is that it connects people. In many cases that direct connection has reduced or even completely removed the need for an organisation – whether it's a business or a government department – to get involved. This might sound great, but if you're the company involved it's not so good – it means you have no chance to acquire a customer or make a profit.

The challenge that Microsoft has faced from the free GNU/Linux operating system, built by thousands of unpaid developers linked together online, is the best-known example, but there are many others. Car-sharing schemes, for example, are an excellent resource for people who need a car only occasionally, and you can now spot Zipcar spaces in many car parks. It's a great example of how online efficiencies permit new business models to emerge.

However, a new service pioneered in the US challenges even this stripped-down approach. RelayRides acts as an "eBay for car rentals" that lets car owners rent out their own cars. RelayRides covers the insurance and admin costs and takes a cut, but doesn't have to buy any cars itself. Something similar is happening with hotels: services like iStopOver, Airbnb and Crashpadder connect people with spare rooms directly to those who need them.

Sometimes you don't even need a business to trade online. My friend Jake is a big opera fan, and buys tickets in advance for the whole season at London's Royal Opera House. He always buys at least two tickets, then posts a Google Doc with times and dates of all the performances and emails his list of opera-loving friends, who choose the ones they want. This takes touts and ticket resellers out of the transaction altogether, saving everyone time and money.

It's simple, effective and efficient – and if someone drops out at the last moment then he offers the ticket on Twitter. That's the internet in action.

Bill Thompson contributes to news.bbc.co.uk and the BBC World Service

WEB HACKS

Turn your Twitter feed into a bespoke online newspaper with Paper.li

What? Paper.li turns the people you follow on Twitter into your personal newshounds. It takes their tweeted links and presents them in a newspaper website format. Each story is presented with a picture, its own headline and a brief introduction, while the original tweeter is credited with a byline. Topics, like Technology and Business, are pulled out into different sections and a clever algorithm organises content by importance.

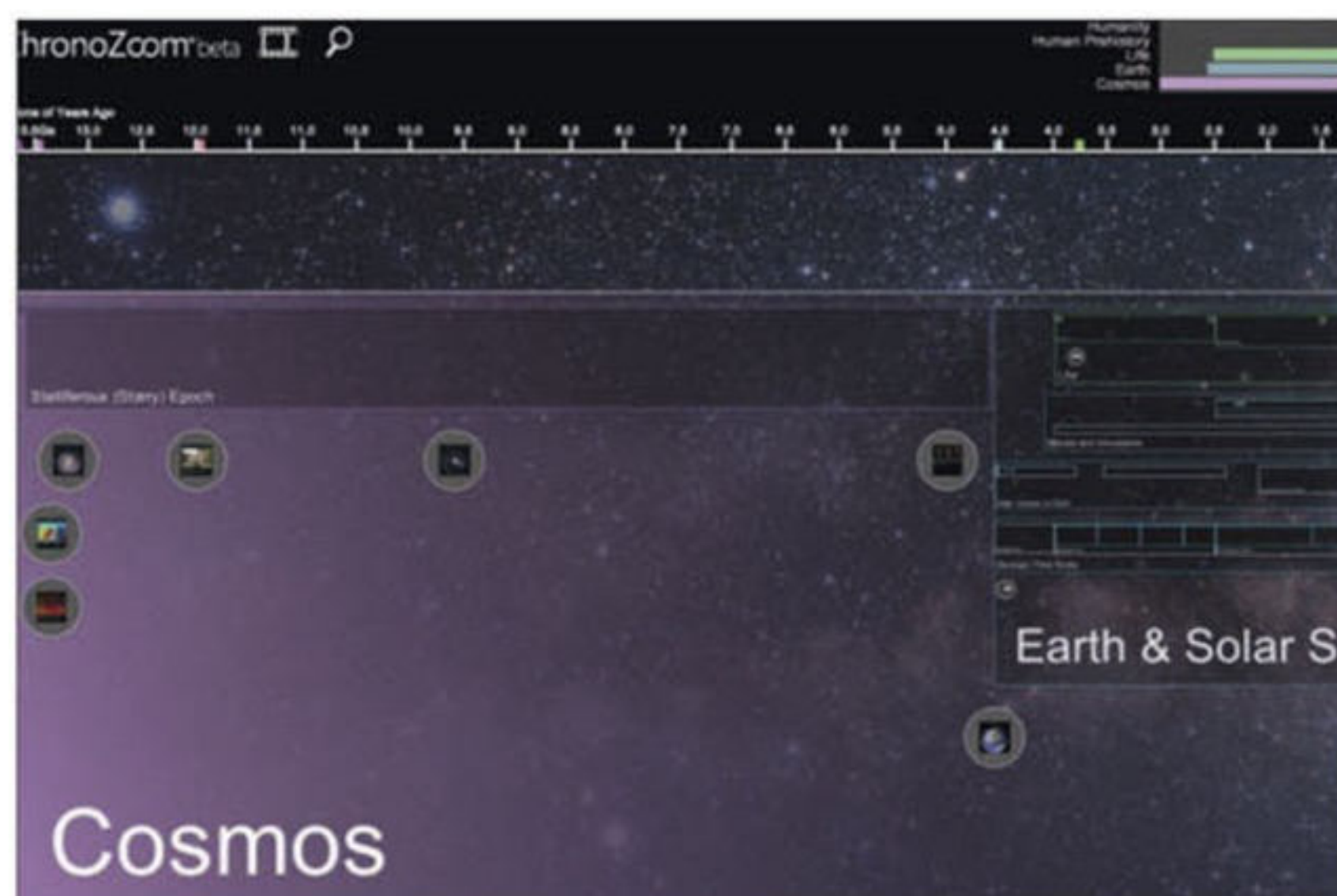


Why? Inane tweets are just as common as meaningful ones on Twitter. Paper.li saves you sifting through a deluge of information to find the interesting content. It takes the important stories of the day and presents them in a familiar and digestible layout. You can then use different filters or make 'papers' out of hash tags to customise the output. These can be shared with others, showing them what's important to you.

How? Sign in to Paper.li with your Twitter account and it'll automatically draw up a paper from the people you follow. From there you can tweak and specialise your own papers, share them on your social networks or view those made by friends.

Chronozoom

www.chronozoom.org



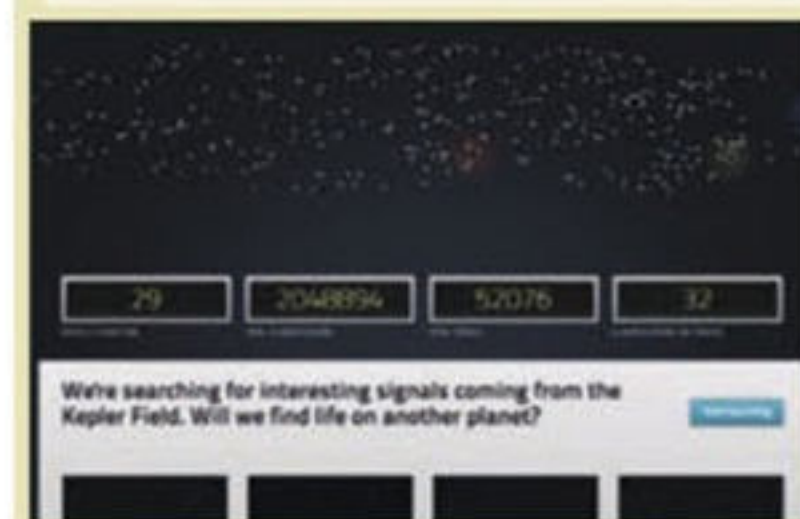
Our lifetimes are so small in the grand scheme of things that it is hard for any human to wrap their head around cosmic timescales. That's a problem that Chronozoom – an interactive timeline charting the 13-billion-year history of the Universe – hopes to solve.

Using your mouse, you can zoom into various 'thresholds' – significant cosmological events such as the formation of the first stars, or the origin of life – to find engaging multimedia explanations. Not all of these are filled out (the site is currently in beta), but what is there looks promising, and it will only get richer with time.

But even in this incomplete form, Chronozoom does a great job of putting the mindboggling scale of time into the context of our existence. In particular, look out for the origin of human beings. We arrive at the very end, with human history in its entirety inhabiting a stretch of time so small that it barely fills a pixel when the timeline is completely zoomed out.

SETILIVE

Setilive.org



SETILIVE, a collaboration between the SETI Institute, Zooniverse and TED, enables the public to help in the search for extraterrestrial life. The site shows real data collected by the Allen Telescope Array in California and tasks you with classifying images that automatic detection systems would ignore because they contain too much radio interference. Human eyes are much better at finding interesting signals in this man-made noise, so go and put yours to good use.

Stephen Hawking Birthday Symposium

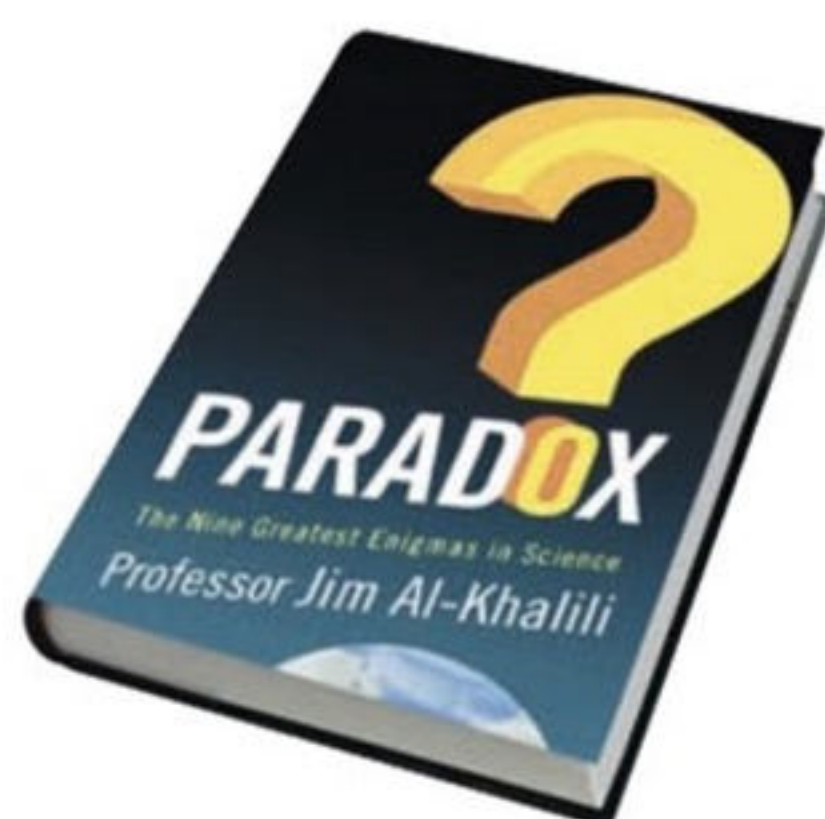
j.mp/HawkingSymposium



Earlier this year, some of the world's most prominent physicists gathered in Cambridge to celebrate Stephen Hawking's 70th birthday. If you didn't get an invite, this website is the next best thing. Here you can watch the day's talks, along with a pre-recorded talk from Hawking himself, 'A Brief History Of Mine'. Listen out for the cosmology in-jokes and recollections of the various bets Hawking made with other scientists throughout his career.

Paradox

A layman's guide to some of the greatest mysteries in physics, says **Prof Jeff Forshaw**



The Nine Greatest Enigmas In Science
Jim Al-Khalili
Bantam Press, £16.99
(234pp, hbk)

Why is the sky dark at night? How can a 5m-long pole fit inside a 4m-long barn? And is time travel possible? These are some of the questions that physicist Jim Al-Khalili tackles in this enjoyable little book. Despite its subtitle – promising to tackle science's

greatest enigmas – *Paradox* is mainly about physics. Professor Al-Khalili confronts some famous paradoxes and successfully introduces ideas that form the foundations of modern physics.

The book starts with a handful of paradoxes that have nothing to do with science – quirky logic problems that are great fun to play with. These whet the appetite for what follows: serious physics presented in a highly accessible fashion. We're taken on a journey that takes in the Big Bang, perpetual motion machines, time travel, chaos theory, extraterrestrial life and even free will. Al-Khalili is at his best when discussing the physics – the explanations are extremely clear, and he manages to avoid mathematics and too much technical detail.

The occasional meanderings into metaphysics do add to the general spirit of inquiry that

Paradox promotes, but here the arguments aren't so clearly articulated. The light, informal prose makes for an easy read, but by the end of the book I was tiring of the clichéd patter and the excessive use of the word 'indeed'.

But these are minor quibbles – this book is, above all, enormous fun. Modern physics has delivered a world view that lays bare the limitations of our human intuition. The Universe is a far more exotic place than even the most surreal imagination could dream up. And we know all this thanks to our enduring desire to ask ever deeper questions, coupled with our ability to conduct ever more precise experiments and observations. *Paradox* is a celebration of that endeavour. ●●●●○

Prof Jeff Forshaw is a particle physicist and co-author of *The Quantum Universe*



Jim Al-Khalili
on *Paradox*

Why did you decide to write this book?

I'd been chatting on Twitter about relativity, quantum physics and brain teasers, and thought, 'I wonder if anyone's written a book on paradoxes in science?' A lot of the material – the twin paradox, time travel, Schrödinger's cat – is what I teach to students. I wanted to explore the mind-bending side of it, to try and baffle people, and then explain the science. This is the first book I've written that should appeal to people who want to be stretched intellectually.

What surprised you most?

The 'game show paradox' – it's not physics, it's logic. What surprised me most is the history: even mathematicians were puzzled when it first came to light, and yet it's so simple. Usually with paradoxes, even when you hear the explanation, it's not quite as satisfying as you'd like it to be. With this one, there are two or three different ways of explaining it where the penny really does drop.

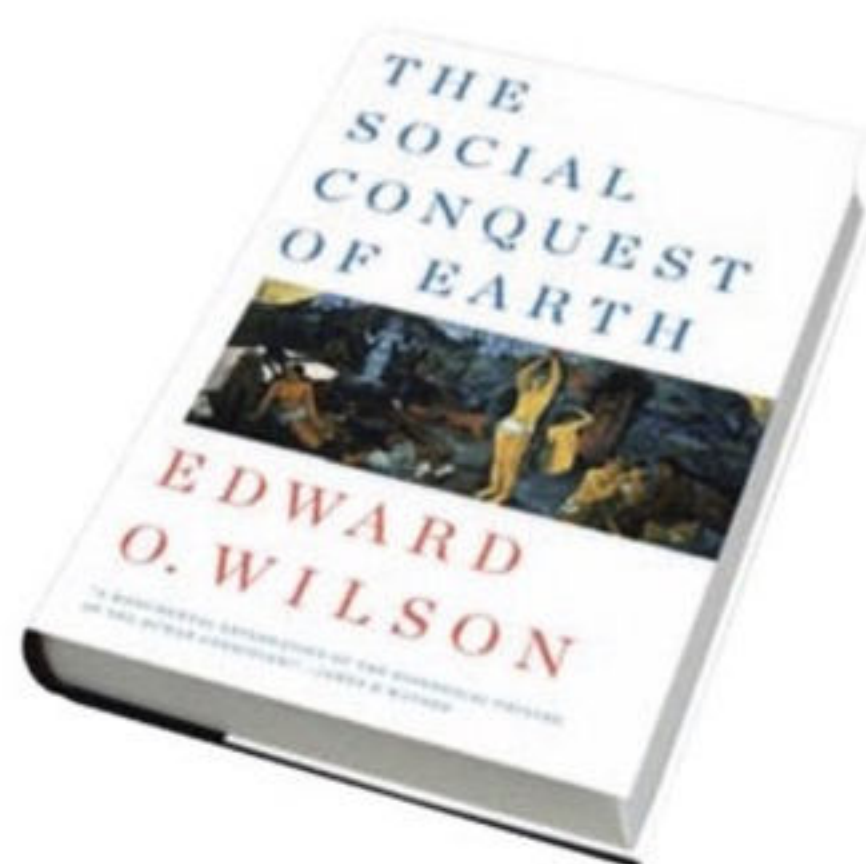
Which part of the book was most challenging?

A chapter on 'Maxwell's demon', violating the second law of thermodynamics. That's the law that says heat will always flow to cooler objects: things unwind, balls roll downhill. And yet James Clark Maxwell, a 19th century Scottish physicist, devised a paradox with a hypothetical demon who can – through knowledge – violate this fundamental law of physics. It's far more subtle than I ever appreciated, and I had a wonderful time trying to get my head around that.

Listen to Professor Jim Al-Khalili describe paradoxes in more detail on the Focus podcast: <http://j.mp/focast>



Time travel via wormholes is just one of many hot topics addressed in *Paradox*



The Social Conquest Of Earth
Edward O Wilson
 Norton, £18.99
 (352pp, hbk)

The origin of altruism has been a question at the heart of evolutionary biology for decades. If genes are basically selfish, how can societies – which are made up of co-operating individuals – ever get started? The standard answer has been a concept called ‘kin selection’: the genes of individuals can still be passed on if sacrifices are made for one’s close relatives.

Practically dogma for four decades, kin selection has recently been challenged by several scientists, notably the myrmecophile (ant-lover) Edward O Wilson. In place of kin selection, Wilson has promoted the idea that natural selection for selfishness in individuals competes against selection on traits that would benefit groups. This new view is controversial, but many of the points of debate are very technical and won’t find a place in a book like *The Social Conquest Of Earth*.

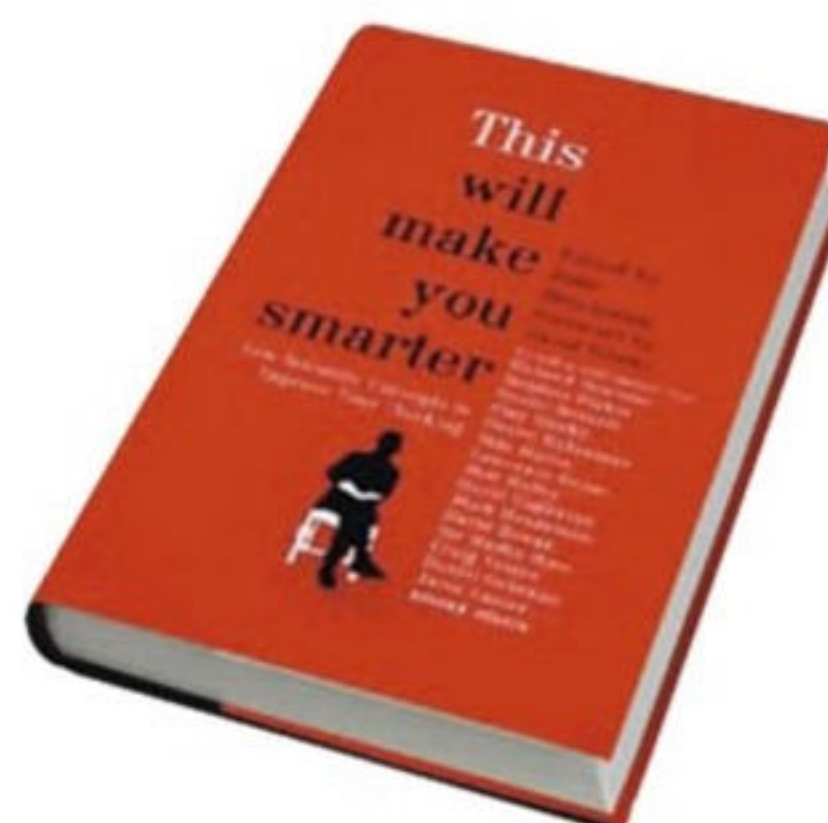
So what we have here is Wilson’s view dressed up with anecdotes from a career comparing insect societies with those of humans; the conventional platitudes about how wonderful we are; the dreadfulness of religion; how we’re destroying our planet; florid phrases about the ‘flowering of the human genius’ and so forth... yawn. It’s all well-intentioned, but oh-so-pompous. As Mozart says in the film *Amadeus*: “Wouldn’t you all rather listen to your hairdressers than Hercules?” ●●○○○

Dr Henry Gee is a senior editor at the journal Nature

This Will Make You Smarter
John Brockman (editor)
 Doubleday, £14.99
 (448pp, hbk)

Imagine inviting some of the world’s top thinkers round to your place and asking them to tell you one thing that would make you smarter. No need to imagine: John Brockman has done it, by getting 150 of the planet’s smartest minds to proffer a neat insight each.

The idea was suggested by Harvard psychologist Steven Pinker, who duly supplies the quintessential example, a short essay showing that many situations in life look like ‘zero-sum’ games where only one side can win, when a little thought could turn them into ‘positive sum’ games where both sides win. There are many similar offerings, like technologist Paul Saffo’s view that people work best if the time scale for success makes sense to them, and physicist Carlo Rovelli’s tip about the dangers



of certainty. Indeed, dealing with uncertainty is a common theme throughout the book.

Inevitably, a few of the 150 contributions are a bit hackneyed, abstract or just plain cobbles. But at 10p per insight, buying this book is definitely the smart move.

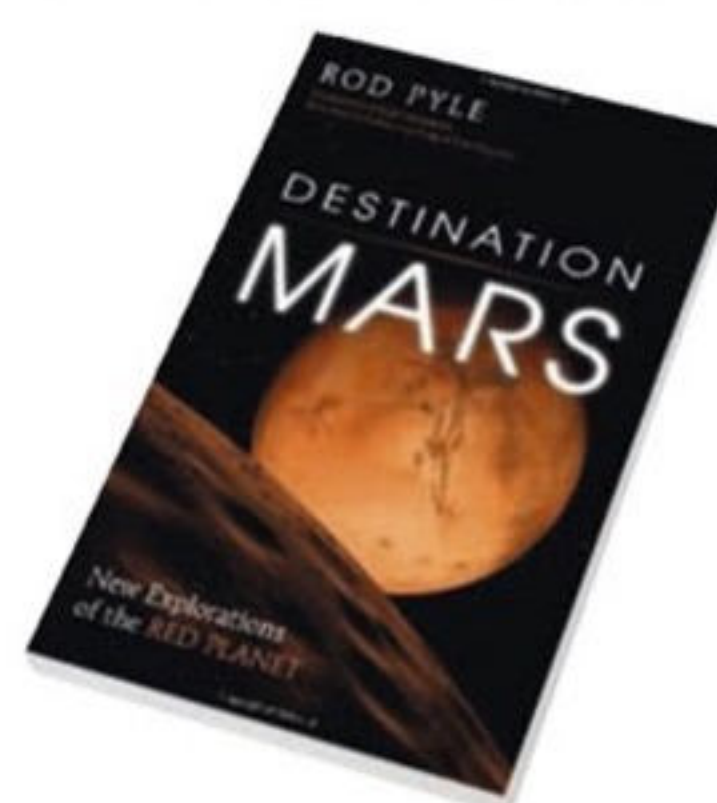
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Robert Matthews is visiting reader in science at Aston University

Destination Mars
New Explorations Of The Red Planet
Rod Pyle
 Prometheus, £16.99
 (280pp, pbk)

Destination Mars presents a history of Mars exploration by NASA’s Jet Propulsion Laboratory. Beginning with the early Mariner space probes, Rod Pyle guides us expertly through the legacy of the Viking programme, the successes of Spirit and Opportunity, and highlights from a host of other missions over the last five decades.

Often amusing and anecdotal, *Destination Mars* captures some of the angst faced by mission controllers, the relief or disappointment of engineers and the delight or surprise of planetary scientists. It’s interspersed with short vignettes in which Pyle gives voice to key figures in Martian exploration. While these are interesting and relevant, the first-

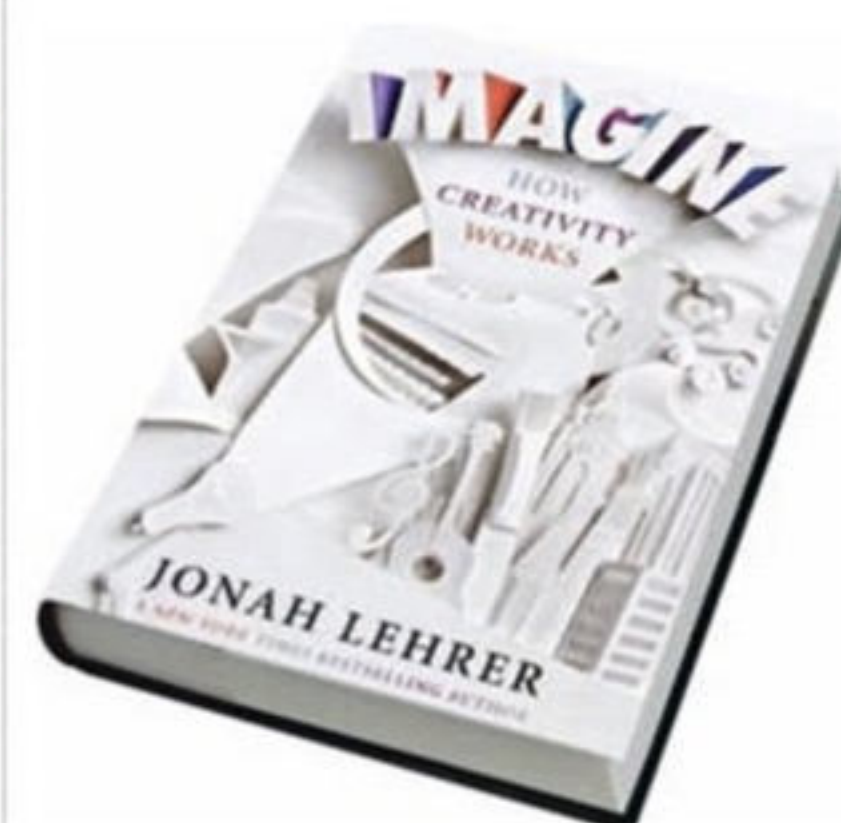


hand experiences and views of those involved could possibly have been better woven into the fabric of the historical narrative.

Although the title and cover notes suggest an in-depth discussion of future missions, this is in fact only a minor part of the book. Nevertheless, for anyone seeking a succinct yet thorough overview of our knowledge of the Red Planet, there can be no better book than *Destination Mars*.

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Dr Alastair Gunn is an astronomer at Jodrell Bank Observatory



Imagine
How Creativity Works
Jonah Lehrer
 Canongate, £18.99
 (280pp, hbk)

At an exhilarating pace, Lehrer takes us from the symphony of the human brain to the social conditions that prevailed in Elizabethan England. The general thesis of the book is simple: creativity is not one thing, and there is no single, secret factor behind creative success.

Instead, we need to look both inside and out. If we’re going to understand where new ideas come from, we need to examine ourselves – alone, together in groups and society at large. Lehrer enriches the discussion of neuroscience, psychology and sociology with examples from artists he admires, but the sheer genius of people such as Dylan and Shakespeare makes the science of creativity look feeble, even when described in Lehrer’s clear, engaging prose.

Although Lehrer’s equally comfortable discussing the neurochemistry of insight as he is in describing innovations in schooling in 16th century England, I couldn’t shake the feeling that, in taking on the subject of creativity, he has bitten off rather more than he can chew. Creativity is central to human culture, and to human cognition. This short book, which sets out to cover such a breadth of topics, can never really do much more than scratch the surface.

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Dr Tom Stafford is a psychologist and the co-author of Mind Hacks

THE TO-DO LIST

The essential guide to the month ahead

5 MAY

The Brain Observatory

As Director of the Brain Observatory at the University of California, San Diego, it's Jacopo Annese's job to collect brains. One of these brains in particular has shaped much of what we know about human memory. Annese tells BBC Radio 4 presenter Claudia Hammond the story of its donor, Henry Gustav Molaison, and explains how his posthumous contribution has influenced modern neuroscience.

The Wellcome Centre, London, 2pm-3pm, free, www.wellcomecollection.org



8 MAY

Dr Simon Mitton

Who is he?

Astrophysicist Dr Simon Mitton is Director of Studies in the History and Philosophy of Science at St Edmund's College at Cambridge University. He is the biographer of the famous cosmologist Sir Fred Hoyle, and has researched the life of many other science greats such as astronomer Nicolaus Copernicus and polymath Mary Somerville.

What's he talking about?

The origin of structure in the Universe. The lecture will delve into the history of mankind's attempts to understand the mechanics and architecture of the cosmos, which led to the discovery of the Big Bang and the elusive phenomena of dark matter and dark energy.

Royal Astronomical Society, London, 1pm-2pm, free, www.ras.org.uk

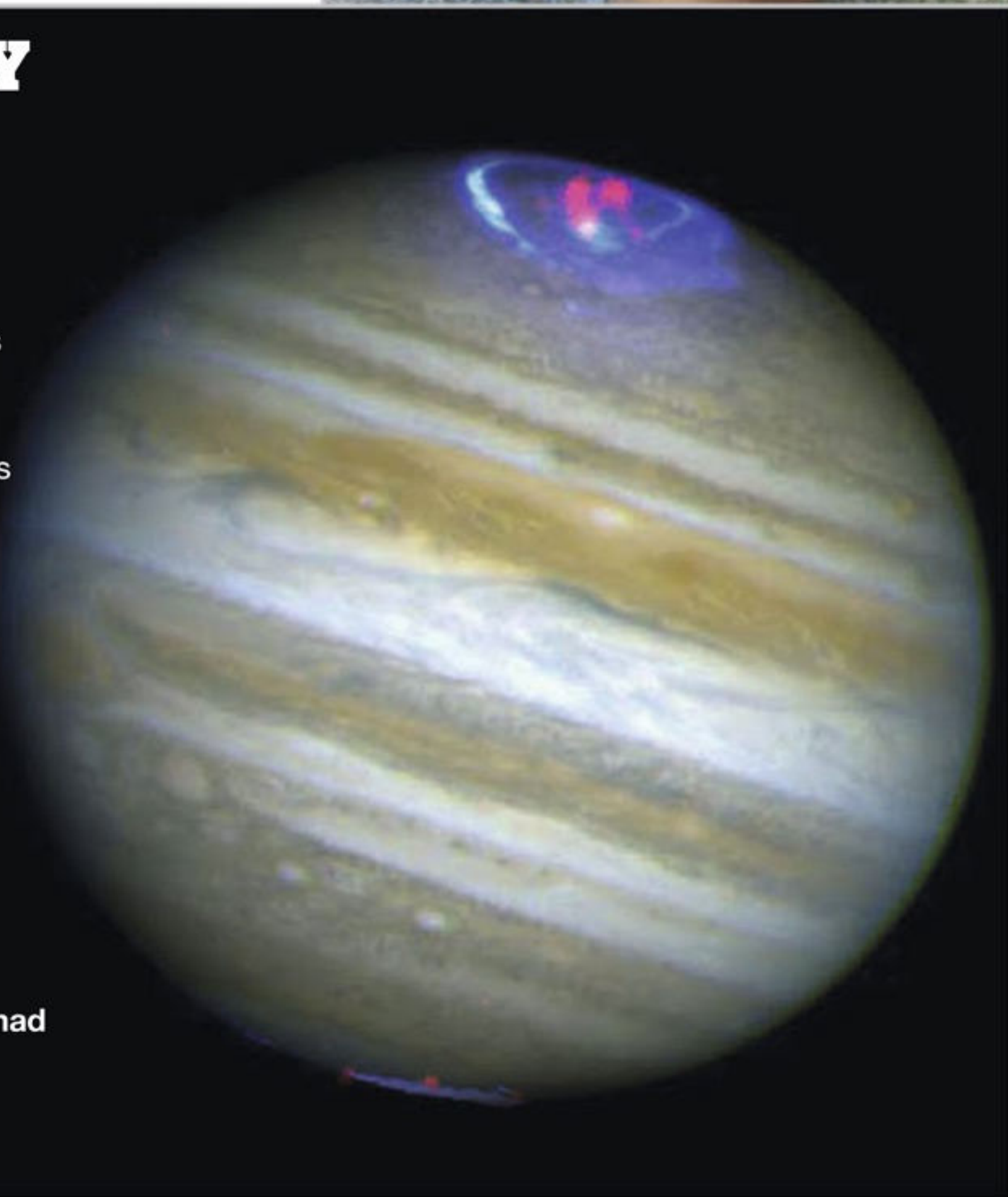
SPEAKER OF THE MONTH

12 MAY

Merseyside Astronomy Day

Professional astronomers gather at Liverpool John Moores University's Spaceport to give a series of talks about some of the most incredible objects in the Galaxy. Between lectures on Jupiter's hotspots, and exploding stars, visitors are also free to roam the exhibits or take in a planetarium show.

Spaceport, Wirral, £8 adults, £4.50 children, 10.45am-4.30pm, www.astro.ljmu.ac.uk/mad



16 MAY

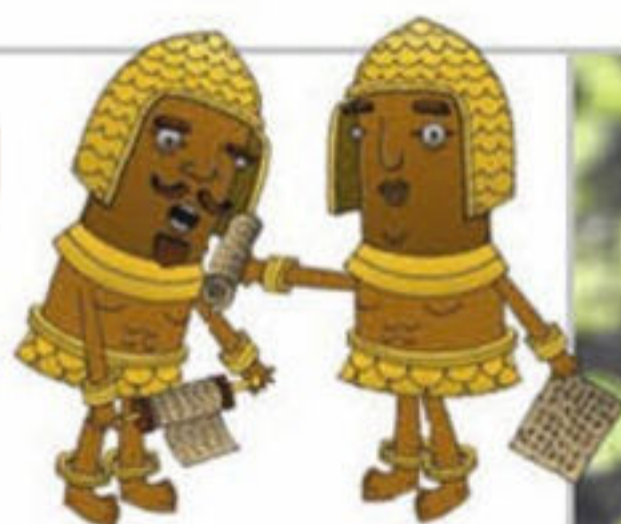


FutureEverything

After listening to the likes of MIT's SENSEable City Lab head Carlo Ratti, emerging tech expert Andy Miah and e-democracy guru Ian Brown, expect to be inspired to launch your own start-up in Swindon Valley. But after all that blue-sky thinking, just be prepared for the Monday morning office reality check...

MOSI, Manchester, 16-19 May, prices vary, futureeverything.org

**17
MAY**



Exploring Hieroglyphs

Ever fancied deciphering Ancient Egyptian symbols? Find out how from Dr Angela McDonald, as she explores their development and how they fit in with the other writing systems used centuries ago.

National Museums Scotland, Edinburgh, 6pm-7pm, free but places limited, call 0300 123 6789, www.nms.ac.uk



27 MAY

Big Nature Day

Go bug hunting, explore pond life and discover uses for the rambler's greatest foe, the nettle, at the Natural History Museum's annual nature fair. Experts will reveal their favourite species and, on a more serious note, discuss the value of biodiversity. Plus, find out how you can help survey your local environment in the Backyard Biodiversity talks at 12.30pm and 2.30pm.

Natural History Museum, London, 11am-5pm, free, www.nhm.ac.uk

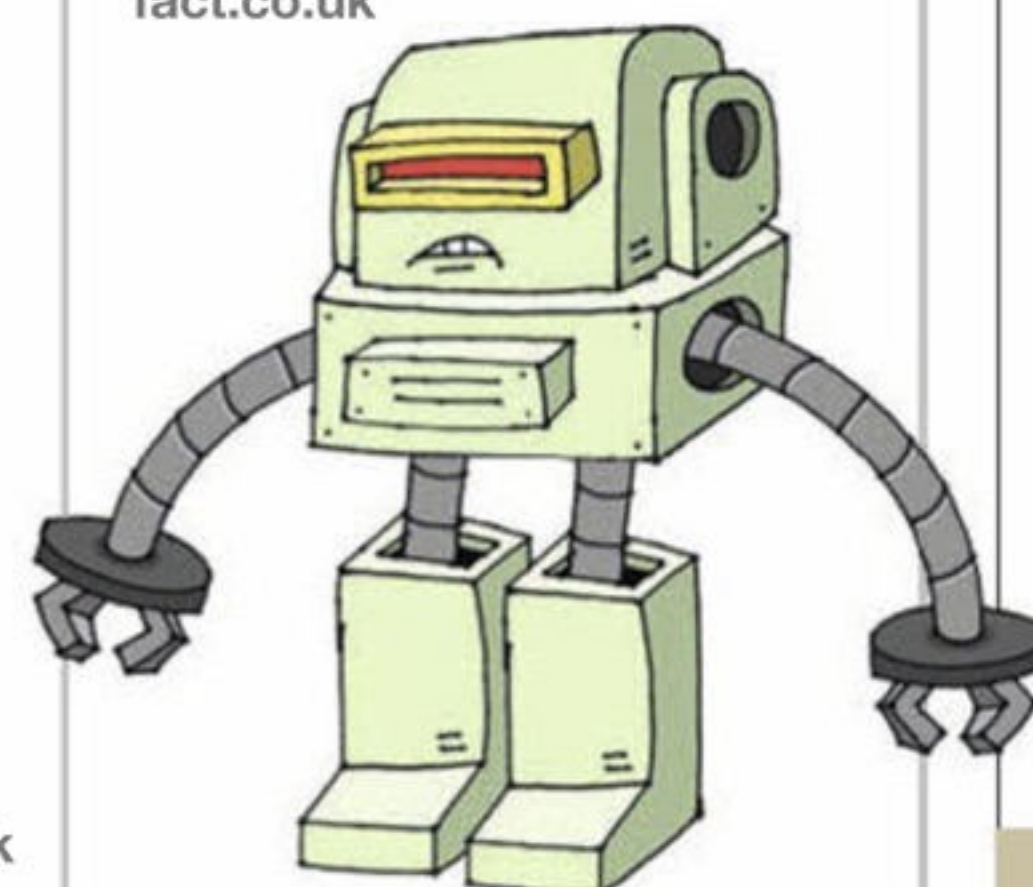
**27
MAY**

**LAST
CHANCE TO SEE**

Robots And Avatars

In a recent survey, 38 per cent of kids said they wanted to learn with a robot. While we scratch our heads and wonder why on Earth the other 62 per cent didn't, you can catch this exhibition which showcases works of art, animation and augmented reality. It explores how robots and avatars will impact the future of work, rest and play.

FACT, Liverpool, free, www.fact.co.uk



28 MAY

Do We Need Friends?

Although nowadays we may opt for a catch-up on Facebook rather than meeting up at the pub, we continue to seek out friendships. At this Café Scientifique event, join Prof Neil Macrae as he delves into the benefits of socialising and why we need friends, despite technology changing the way we make them.

Royal Society, London, 6.30pm-8pm, free, royalsociety.org



31 MAY

Hay Festival

The highlight of the literary calendar brings the science big guns out in force. Jim Al-Khalili will be exploring the greatest enigmas in physics, while fellow physicist Frank Close investigates quantum field theory. Add to the mix Susan Greenfield on the neuroscience of identity, James Watson on the

discovery of the structure of DNA, CERN Director Rolf-Dieter Heuer on those pesky neutrinos and a host of others besides. And if you need a break from all that heady science, then comedian Tim Minchin will be performing in the evenings.

Hay-on-Wye, 31 May-10 June, prices vary, www.hayfestival.com



**DON'T
MISS**

TV & RADIO

The month's top science programmes

Planet Earth Live



BBC One
Starts 6 May

Like *Springwatch* but on a global scale, *Planet Earth Live* follows and films a month in the life of some of the planet's most iconic wildlife.

Can Maasai Mara lioness Joy cut it as a single mum? Will giant otter parents Sophia and Diablo save their cubs from the carnivorous clutches of the Amazonian caiman crocodiles? And what will happen if the Svalbard polar bear cubs tread on thin ice? Join presenters Richard Hammond and Julia Bradbury to watch the real-life drama unfold.

The series, which seeks to marry the real-time filming techniques of shows such as *Springwatch* with the spectacular cinematography of epic documentaries like *Life* and *Frozen Planet*, looks set to become one of the BBC Natural History Unit's finest moments. Filmed across six different time zones and thousands of miles, *Planet Earth Live* is a biotic bonanza with an all-star cast that is both cute and cunning, winsome and wild. But a word of caution if you're a grey whale calf – make sure you watch out for those orcas...

Sundays 8pm, Thursdays 8pm, Wednesdays 7.30pm



Follow the day-to-day lives of polar bears in *Planet Earth Live*

Hidden Talent



Channel 4
Throughout May



Have you ever felt you've got a special gift just waiting to be unleashed? Maybe you're a latent linguist or a dormant diver? Now's your chance to find out. The team at *Hidden Talent* screened hundreds of participants with special tests designed to highlight latent ability, then chose eight for fast-track training to top class level. Follow Richard Bacon as he charts their progress,

uncovering the science that enables these individuals to achieve what others can only dream of – one hones an extraordinary sense of direction to become a veritable human sat-nav, while another learns to dive deep without scuba gear to become an expert free-diver. Then take the online test to find out if you have a hidden talent of your own. The interactive challenges might just help you unleash your inner superpower.

Million Dollar Moon Rock Heist



National Geographic Channel
10 May, 9pm

It sounds like the plot from a straight-to-DVD movie, but it's all true. Trying to impress his girlfriend, NASA trainee Thad Roberts breaks into the Johnson Space Center and steals a safe full of priceless Moon rocks. The couple make love on top of the stolen fragments, boasting they are the first people to have 'sex on the Moon'; Roberts then tries to sell the rocks to Belgian mineral collector Axel Emmermann, but he's working with the FBI, and the rocks are returned to NASA – albeit slightly soiled! *Million Dollar Moon Rock Heist* recreates the story of this bizarre lunar burglary. The lesson – next time your partner promises you the Moon, walk away.



Danger In The Download BBC World Service Starts 1 May

The internet began life as a means of sharing data between research institutions, whose members mostly knew each other. Today, it's used by a staggering 2.3 billion strangers all over the world, including hackers, vice peddlers and political extremists. So are the net's original architecture and governance still fit for purpose? Ed Butler assesses the ever-increasing threats from hackers, criminals and cyber warfare, and asks what can be done to protect internet users without encroaching on their liberties.

Tidal Talk From The Rockpool Radio 4

Starts 8 May, 11pm
Eats, Shoots And Leaves author Lynne Truss turns her hand to radio in these salty tales from the seaside. Alison Steadman is an anemone, while Tony Robinson brings out his inner lugworm in a light-hearted tale of life between the tides. It was recorded in front of a live audience at Radio 4's More Than Words festival, which was held in Bristol in March.

Healthcheck BBC World Service Wednesdays

Explore the science of staying healthy with the BBC World Service's long-running weekly medical programme, as psychologist and award-winning broadcaster Claudia Hammond reports on new discoveries and burning questions in global and personal healthcare.



Killers Week

eden Eden HD
22/23 May, 6pm/8pm



Venom Island studies the top predators of Sunda Island in Indonesia, which use toxins to subdue their prey. The *King Of Sunda* is the Komodo Dragon, whose prehistoric origins are explored in Dr Bryan Fry's documentary. And if the beasties on land weren't bad enough, the cannibalistic nightmare of *The Ragged Tooth Shark* proves it isn't much safer in the water.

Around The World In 80 Ways

travel & living Travel And Living
Starts 5 May, 6pm



Thrill-seekers Dennis Anderson and Rob Mariano battle the elements and each other, in a dramatic race around the globe with a twist. The contestants must complete their journey using 80 different modes of transportation. The series highlights just how much travel has changed since the first rickety motors took to the roads, as the rivals attempt to steal pole position on unicycles, railway handcars and B1 bombers.

Life On Fire

eden Eden
Starts 9 May, 8pm

Erupting onto our screens with more lava than a 1960s lamp, this four-part mini-series focuses on one of nature's most powerful forces, volcanoes, and how they help to shape their environment. Using aerial HD photography of eruption sites, the films bring to life the habitats and ecology surrounding some of the most active volcanoes on the planet.



Penn And Teller Tell A Lie

QUEST Quest
Starts 2 May, 9pm

The charismatic conjurors explore the science behind some of the world's strangest feats – like steering a plane with its doors or melting steel with bacon. But there's a twist: one of the seven stories in each episode is fake, with the culprit only revealed at the end. The first episode includes the fact that a deep B flat played on a tuba can be used to encourage alligators to mate, so it's going to be hard to pick out the red herrings.



Stalked

ID. Investigation Discovery
Starts 2 May, 9pm



Every year, three million people become victims of stalking in the US alone. The psychological scars can last a lifetime. But what drives a person to become a stalker? Criminal psychologist Dr Michelle Ward aims to find out. Telling victims' stories and examining the psychology of perpetrators, *Stalked* reveals the difficulties of combating this obsessive behaviour.

Animal Superpowers

NAT GEO WILD Nat Geo Wild
Starts 3 May, 8pm



Sadly not a show about a band of animals with superpowers taking on evil criminal masterminds. Instead, Patrick Stewart narrates this three-part documentary about how animals have evolved abilities that would seem more at home on comic book pages. The 'heroes' include an electric eel that can give a hungry shark a heart attack, and hammerheads that capitalise on electromagnetic fields to home in on their prey.

Are You Buying Pre-Ruined

The Music Chain

Much is written about music and the musicians who entertain us, and we rightly exalt great musicians. But there is an interlinked chain of participants, two of which are I believe are crucial to our music scene in today's world. For centuries the music chain was a very short one – composers or songwriters, musicians and listeners, and the judgement on quality was immediate. Recording technologies have changed all this exponentially.

Today, we listen to most of our music from a recording and this gives recording engineers the opportunity to avoid poor acoustics, duff notes and off days. This, of course, means the chain has grown to include the recording engineers, the music distribution system (retailers or downloads), hi-fi manufacturers, hi-fi sellers and the hi-fi purchasers, the latter being the listeners. I should start by saying that hi-fi has become an adulterated term that no longer has its original meaning because it's applied to much equipment that certainly should not be termed high-fidelity.

It's said that a chain is only as strong as its weakest link. However, I believe there are two particularly strong links that, if removed from the chain, would seriously damage the quality of recorded music. These are the audiophile, or hi-fi connoisseur, and the specialist hi-fi retailer, the latter in nearly all cases also being the former because it's their interest that has driven them into their particular business. These are the people who most appreciate how exciting and involving music can be and how it can deliver an emotional experience.

Hi-Fi Connoisseurs

So why is the hi-fi connoisseur so important to the music industry? By their nature, audiophiles are generally avid music lovers who enhance their enjoyment through listening to music at its very best quality level, which means playing great recordings

through hi-end hi-fi to achieve the most outstanding results. Without the audiophile, the main driver for quality would probably be removed from the chain. Let's be honest, over recent years the majority of music listeners now settle for MP3 convenience and, therefore, mediocre sound quality, that is 'pre-ruined' music. If the pendulum ever swings so far that all but a few listen to highly compressed formats such as MP3, music producers will not waste their resources on producing high quality recordings because it would be commercially unnecessary, even if their recording engineers wanted to achieve the best they could. After all, an MP3 or AAC file, the iTunes default format, downloaded at 128 kbps (the most popular download speed), is about one-eleventh the size of a full resolution CD track, 1411 kbps, so the quality is inevitably far inferior. Information is irretrievably lost and the full dynamic range is lacking. Using an iPod while jogging does not really raise a quality issue but playing low-resolution tracks through an iPod docking station that feeds into a decent hi-fi system, is a disaster area. It's rubbish quality made louder. Fortunately, there is still significant demand from audiophiles committed to sound quality to sustain the production of high quality recordings, but it would be a tragedy if there weren't. For example, most classical recordings downloaded as an MP3 or AAC file are a complete waste of time because there is so much information missing that they are reduced to just the essence of a tune.

Specialist Hi-Fi Retailers

Just as essential a link in the chain as the hi-fi connoisseur is the specialist hi-fi retailer and the two are rightly dependent on each other. Without the specialist retailer the hi-end hi-fi manufacturer would have to rely on the internet and hi-fi magazine reviewers to try and assess the relative merits and

performance of their products against that of their competitors – a notoriously unreliable decision making process. Specialist hi-fi retailers are constantly being offered new products for assessment and potential stocking and, as it is also their hobby as well as their livelihood, they are greatly interested in achieving the best performance and seeking out the most outstanding products and combinations. More than that though is their relationship with audiophiles for, if they are to stay in business, they must satisfy the most discerning customers in the industry. The reality is that audiophiles and specialist hi-fi retailers are essential to each other.

Future of Recorded Music

What are the future prospects of maintaining high quality music recordings? We must hope that audiophiles, or hi-fi connoisseurs, or perhaps most accurately described, music lovers, will continue to drive the demand for quality. But another important reason for hope within the mass-market is that there is no longer any over-riding reason for MP3 and AAC to have such a following. These formats were designed to overcome very slow download speeds and expensive memory capacity. These are not significant factors for most people now. Full resolution, CD quality, downloads are already available and should become the norm as long as the general public can be made aware of the tremendous quality benefit. This has happened with HD TV so we know this awareness can grow rapidly. In the meantime, we must highly value hi-fi connoisseurs and specialist hi-fi retailers, of which the ones listed on this page represent the UK's finest. Specialist dealers know how to choose the products that combine as a superb system and how to get the best out of it by expert installation in the home. If there's a price premium over an internet purchase, it's probably a small one, but it's unquestionably worth the difference.



The specialist dealers below have been selected because they are known to do an excellent job in guiding customers towards hi-fi that will give years of musical enjoyment and total satisfaction.

OUR TOP 20 UK HI-FI DEALERS

SOUTH

Ashford, Kent

SOUNDCRAFT HI-FI
40 High Street.
t: 01233 624441
www.soundcrafthi-fi.com

Chelmsford

RAYLEIGH HI-FI SOUND & VISION
216 Moulsham Street.
t: 01245 265245
www.rayleighhi-fi.com

Colchester

NEW TECHNOLOGY UNLIMITED
33 Sir Isaac's Walk.
t: 01206 577682
www.newtechnologyunlimited.com

Kingston-upon-Thames

INFIDELITY
9 High Street,
Hampton Wick.
t: 020 8943 3530
www.infidelity.co.uk

Maidenhead

AUDIO VENUE
36 Queen Street.
t: 01628 633995
www.audiovenue.com

Rayleigh, Essex

RAYLEIGH HI-FI
44a High Street.
t: 01268 779762
www.rayleighhi-fi.com

Southend-on-Sea

RAYLEIGH HI-FI SOUND & VISION
132/4 London Road.
t: 01702 435255
www.rayleighhi-fi.com

LONDON

Ealing

AUDIO VENUE
27 Bond Street.
t: 020 8567 8703
www.audiovenue.com

N1

GRAHAMS HI-FI
190a New North Road.
t: 020 7226 5500
www.grahams.co.uk

SW11

ORANGES & LEMONS
61/63 Webbs Road.
t: 020 7924 2043
www.oandlhifi.co.uk

SW20

O'BRIEN HI-FI
60 Durham Road.
t: 020 8946 1528
www.obrienhi-fi.com

SOUTH WEST

Bath

AUDIENCE
14 Broad Street.
t: 01225 333310
www.audience.org.uk

Exeter

GULLIFORD HI-FI
97 Sidwell Street.
t: 01392 491194
www.gullifordhi-fi.co.uk

MIDLANDS

Banbury

OVERTURE
3 Church Lane.
t: 01295 272158
www.overture.co.uk

Birmingham

MUSIC MATTERS
363 Hagley Road, Edgbaston.
t: 0121 429 2811
www.musicmatters.co.uk

Coventry

FRANK HARVEY
163 Spon Street.
t: 024 7652 5200
www.frankharvey.co.uk

Leicester

CYMBIOSIS
6 Hotel Street.
t: 0116 262 3754
www.cymbiosis.com

Nottingham

CASTLE SOUND & VISION
48/50 Maid Marian Way.
t: 0115 9584404
www.castlesoundvision.com

NORTH

Cheadle

THE AUDIO WORKS
14 Stockport Road.
t: 0161 428 7887
www.theaudioworks.co.uk

Chester

ACOUSTICA
17 Hoole Road.
t: 01244 344227
www.acoustica.co.uk

Hull

THE AUDIO ROOM
2 George Street, Hedon
t: 01482 891375
www.theaudiroom.co.uk

York

SOUND ORGANISATION
2 Gillygate.
t: 01904 627108
www.soundorg.co.uk

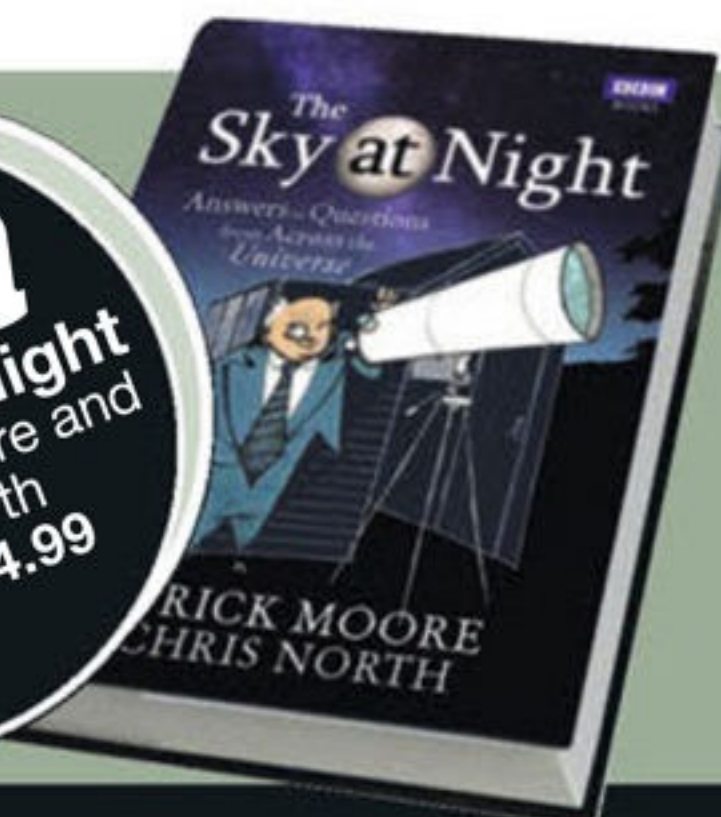
STAR QUALITIES

VALUE FOR MONEY ★ ★ ★ ★ ★
SERVICE ★ ★ ★ ★ ★
FACILITIES ★ ★ ★ ★ ★
VERDICT ★ ★ ★ ★ ★



BRAINTRAINING

Pit your wits against these brainteasers by **David J Bodycombe**, question-setter for BBC Four's *Only Connect*



Prize Puzzle

What number should appear in the middle dot?



The first five correct entries drawn will win a copy of *The Sky at Night: Answers To Questions From Across The Universe* by Patrick Moore and Chris North (BBC Books, £14.99). Post your entry, marked 'Prize Puzzle 242', to: *Focus Magazine*, PO Box 501, Leicester, LE94 0AA by 5pm on 31 May 2012. We regret that we cannot accept email entries for this competition.

See bottom of p82 for terms and conditions. Congratulations to Colin McLean (Edinburgh), Sarah Jane Jones (Comberbach), J Channer (Abertillery), Angus Mclellan (Dunoon) and Clive Roper (Alnwick), who all answered March's Prize puzzle correctly and each win a copy of the *Haynes Millennium Falcon Owner's Workshop Manual*.

See sciencefocus.com/winners for previous winners and solutions

QUESTION 1

What is the educational link between Damien Hirst, Trevor Nunn, Desmond Tutu, Douglas Hurd and Dan Quayle – in that order?

QUESTION 2

If you were to remove the small tetrahedron (left) from each vertex (corner) of the large tetrahedron, what remains?



QUESTION 3

What are the missing letters?

_ _ S _ O N _ _ D
 _ L A _ S _ _ P
 _ A C _ A _
 _ O _ _ O L Y
 _ U E E _ E _ _
 _ N A _ O _ E D
 E P O _ _
 _ I P

QUESTION 4

A certain casino uses chips in \$5 and \$7 denominations. What is the largest bet (in whole dollars) that is impossible to make using multiples of these chips?



QUESTION 5

Paula is making sandcastles in three sizes: 8kg, 17kg and 23kg. If she used 132kg of sand, how many of each size did Paula make?

QUESTION 6

Complete the magic square so that all rows, columns and both main diagonals add up to the same total. (Hint: you may need fractions.)

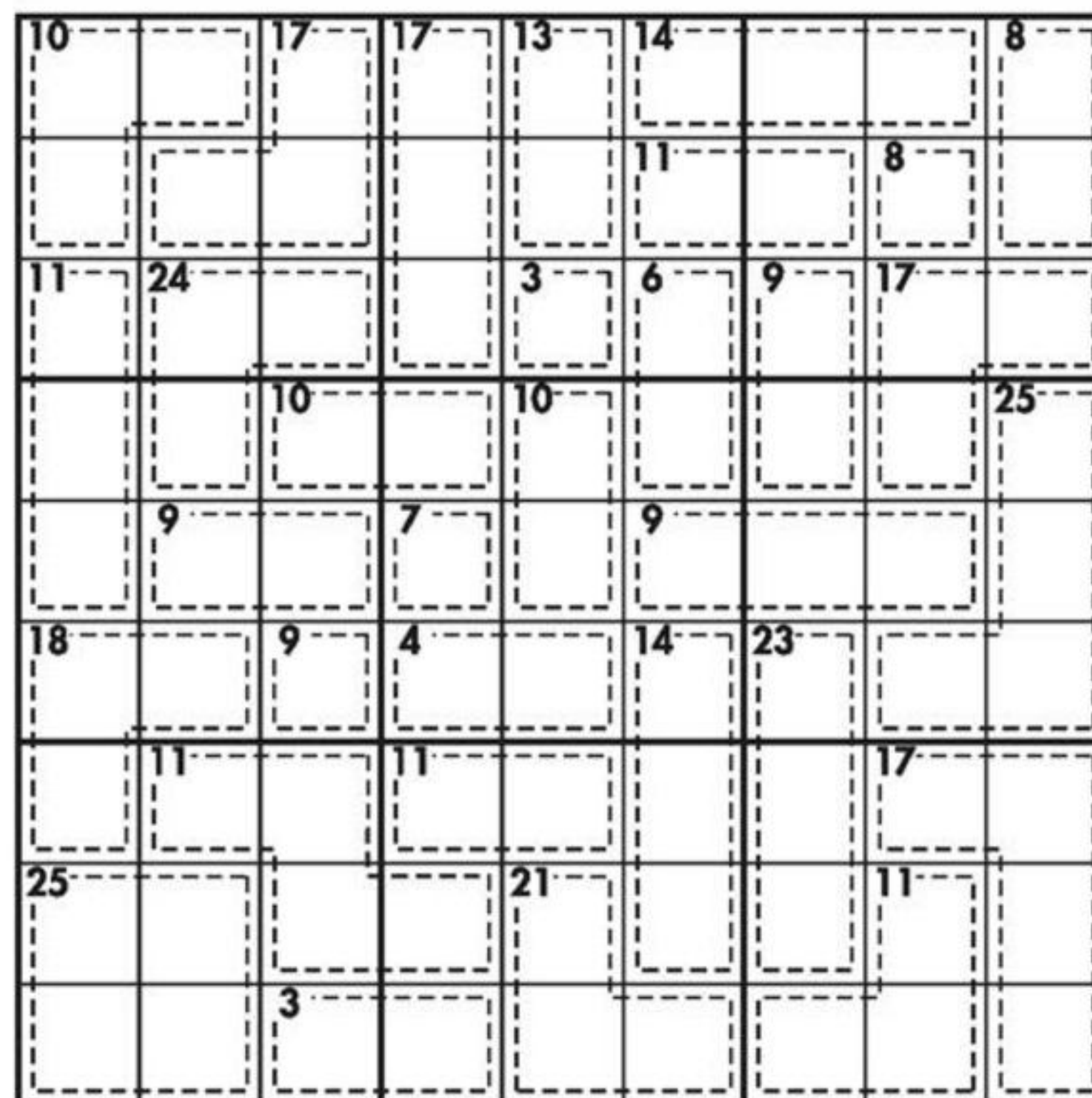
10	A	B
2	C	D
5	E	F

QUESTION 7

One chemical element can be seen within the names of four other chemical elements. Name all five.

QUESTION 8

As per classic Sudoku, each row, column and 3x3 box contains the digits 1 to 9. Also, the digits in each outlined region add up to the total shown. No digit is used twice in any outlined region, even across 3x3 boxes. For example, a three-box region with '24' in the corner must contain 7, 8 and 9 in some order.



Solutions

1	4	8	5	6	2	3	9	7
5	3	6	4	7	9	2	8	1
2	9	7	8	3	1	5	4	6
6	8	1	9	2	5	4	7	3
3	5	4	7	8	6	1	2	9
7	2	9	3	1	4	6	5	8
9	1	3	6	5	7	8	4	2
4	7	5	2	4	3	9	1	6
8	6	2	1	9	8	7	3	5

Q1) They are university student slang for the class of their degrees: first, 2:1, 2:2, third or fail. Q2) An octahedron (figure with sides of eight equilateral triangles). Q3) The alphabet, in order: ABCDEFGH, IJKLMNOP, QRS, TUVWXYZ. Q4) \$23. Since 5 and 7 share no common factors, the way to work this out using a single calculation is: $(5 \times 7) - 5 - 7 = 23$. Q5) Three 8kg, five 17kg and one 23kg. Q6) You need to use fractions: A=2/3, B=19/3, C=17/3, D=28/3, E=32/3, F=4/3. The total for each line always equals three times the middle square, which gives C's value immediately. Q7) Tin can be found inside actinium, astatine, platinum and protactinium. Q8) See illustration.

Quick Quiz

Test your knowledge of extinction

QUESTION 1

Last year, scientists announced plans to clone which extinct mammal?

- a) Thylacine (Tasmanian tiger)
- b) Woolly mammoth
- c) Steller's sea cow

QUESTION 2

According to the IUCN Red List, which of the following species is 'critically endangered'?

- a) Sumatran orangutan
- b) Indian rhinoceros
- c) Komodo dragon

QUESTION 3

Which island in the Indian Ocean was home to the dodo?

- a) Madagascar
- b) Réunion
- c) Mauritius

QUESTION 4

Which of these tiger subspecies is not extinct?

- a) Caspian tiger
- b) Bali tiger
- c) Siberian tiger

QUESTION 5

What was the name of the world's last known surviving Passenger Pigeon?

- a) Martha
- b) Percy
- c) Bob

QUESTION 6

Steller's sea cows, hunted to extinction in the 18th century, lived in which ocean?

- a) Atlantic Ocean
- b) Pacific Ocean
- c) Indian Ocean

QUESTION 7

Roughly how long ago did the Neanderthals become extinct?

- a) 30,000 years
- b) 60,000 years
- c) 90,000 years

YOU ARE:

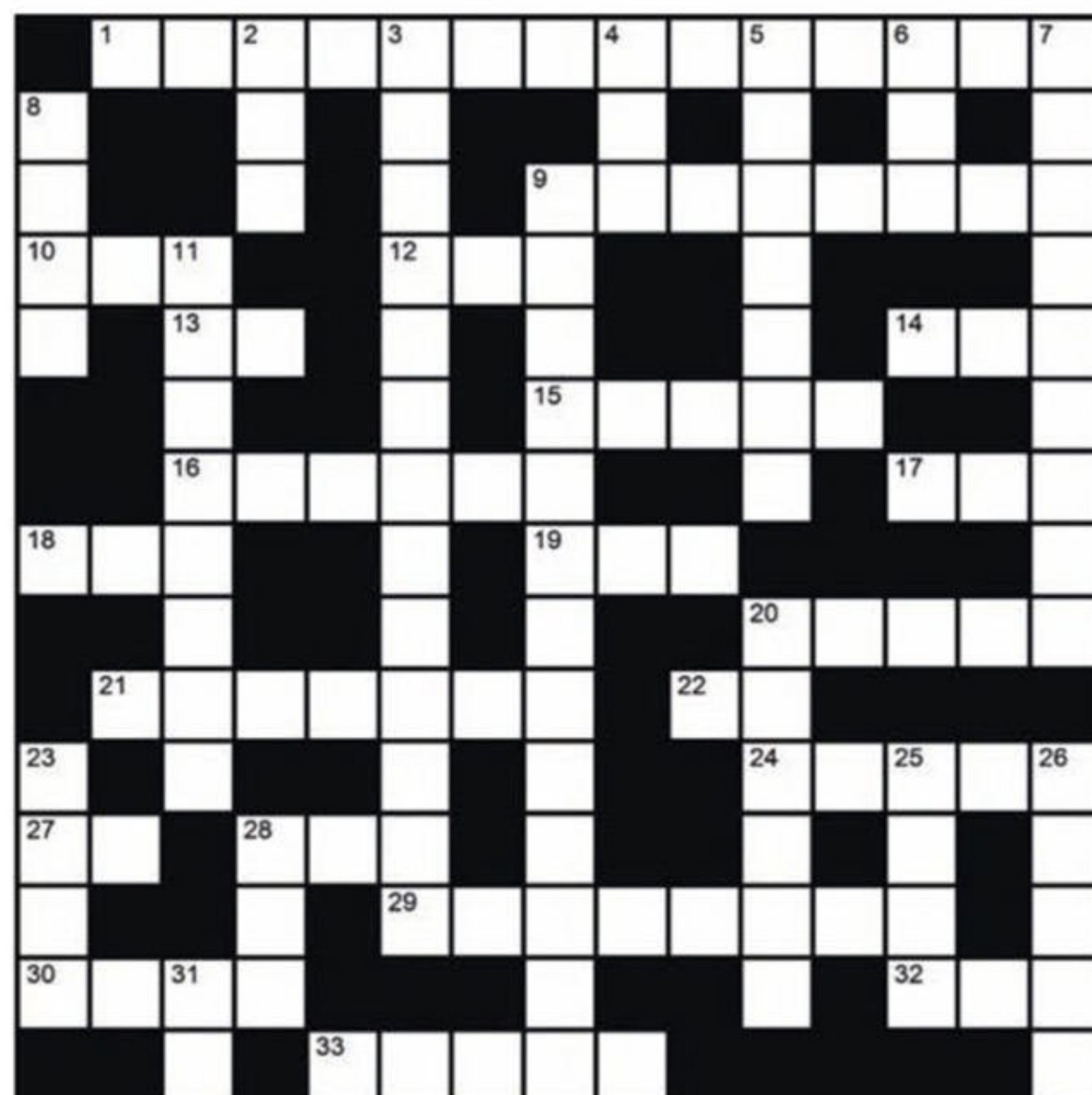
0-2 Walking with dinosaurs

3-5 Dead as a dodo

6-7 Reconstructed from DNA

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Science crossword N°1



Across

- 1 German astronomer, famous for laws of planetary motion (8,6)
- 9 Extinct species of reptile described by Richard Owen (8)
- 10 Abbreviation for compounds formerly used in fridges (3)
- 12 Short wavelength radiation given off by the Sun; affects the skin (3)
- 13 Branch of medicine dealing with childbirth (abbreviation) (2)
- 15 Northern hemisphere constellation with a famous belt of stars (5)
- 16 Biological classification, above Kingdom but below Class (6)
- 17 Type of rock that's often mined for metals (3)
- 18 Organic compound with a double nitrogen bond; often used as a dye (3)
- 19 The surface of Jupiter's moon Europa consists of this (3)
- 20 In particle physics, these carry the strong force between quarks (5)
- 21 Medical condition describing deficiency of iron in the blood (7)
- 22 Abbreviation for a chemical element found in teeth and bones (2)
- 24 The Chandrasekhar _____ refers to the maximum mass a white dwarf star can have before a black hole is formed (5)
- 27 One of the two states described by binary code (2)
- 28 A digit of the foot (3)
- 29 Infinite line on which to plot numbers that are not imaginary (4,4)
- 30 One of the lepton family of elementary particles (4)
- 32 In mathematics, a group of objects (3)
- 33 Contains female reproductive cells in plants (5)

Down

- 2 Abbreviation for virus that causes AIDS (3)
- 3 A positive integer used for counting. (7,6)
- 4 Star found at the centre of the Solar System (3)
- 5 Colourless, flammable liquid; scientific name for drinking alcohol (7)
- 6 Abbreviation for light source, often used for energy efficiency (3)
- 7 It drains the kidney (5,4)
- 8 Crystalline mineral; glints in the light (4)
- 9 Surrounds your stomach, liver, spleen, kidneys etc (9,4)
- 11 Material containing two or more chemically bonded atoms or ions (8)
- 20 A spiral _____ consists of a rotating disc of stars and a central bulge (6)
- 23 A secondary taxonomic rank in botany (4)
- 25 Equivalent to energy (4)
- 26 A beaver's grow continuously (5)
- 28 Metal with multiple uses, including the plating of steel food containers (3)
- 31 Abbreviation for software that runs a computer (2)

Solution to No 138



The first five correct solutions drawn will each win a copy of *Science In Seconds* by Hazel Muir. Entries must be received by 5pm on 31 May 2012, after which the winners will be randomly drawn.

Congratulations to Kenny Black (Airdrie), Brian Morris (Middleton), Alexander Jarvis (Walsall), Grant Naismith (Dumfries) and Janet Berkeley (Frizington) who correctly solved March's puzzle and receive a copy of *Future Science*.

YOUR DETAILS

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Post entries to BBC Focus Magazine, June 2012 Crossword, PO Box 501, Leicester, LE94 0AA or email a scan of the completed crossword or a list of answers to june2012@focuscomps.co.uk by 5pm on 31 May 2012. Entrants must supply name, address and phone number. By entering, participants agree to be bound by the terms & conditions, printed in full on page 82. Immediate Media, publisher of Focus, may contact you with details of our products and services or to undertake research. Please write 'Do Not Contact' on your email or postal entry if you do not want to receive such information by post or phone. Please write your email address on your postal entry if you would like to receive such information by email.



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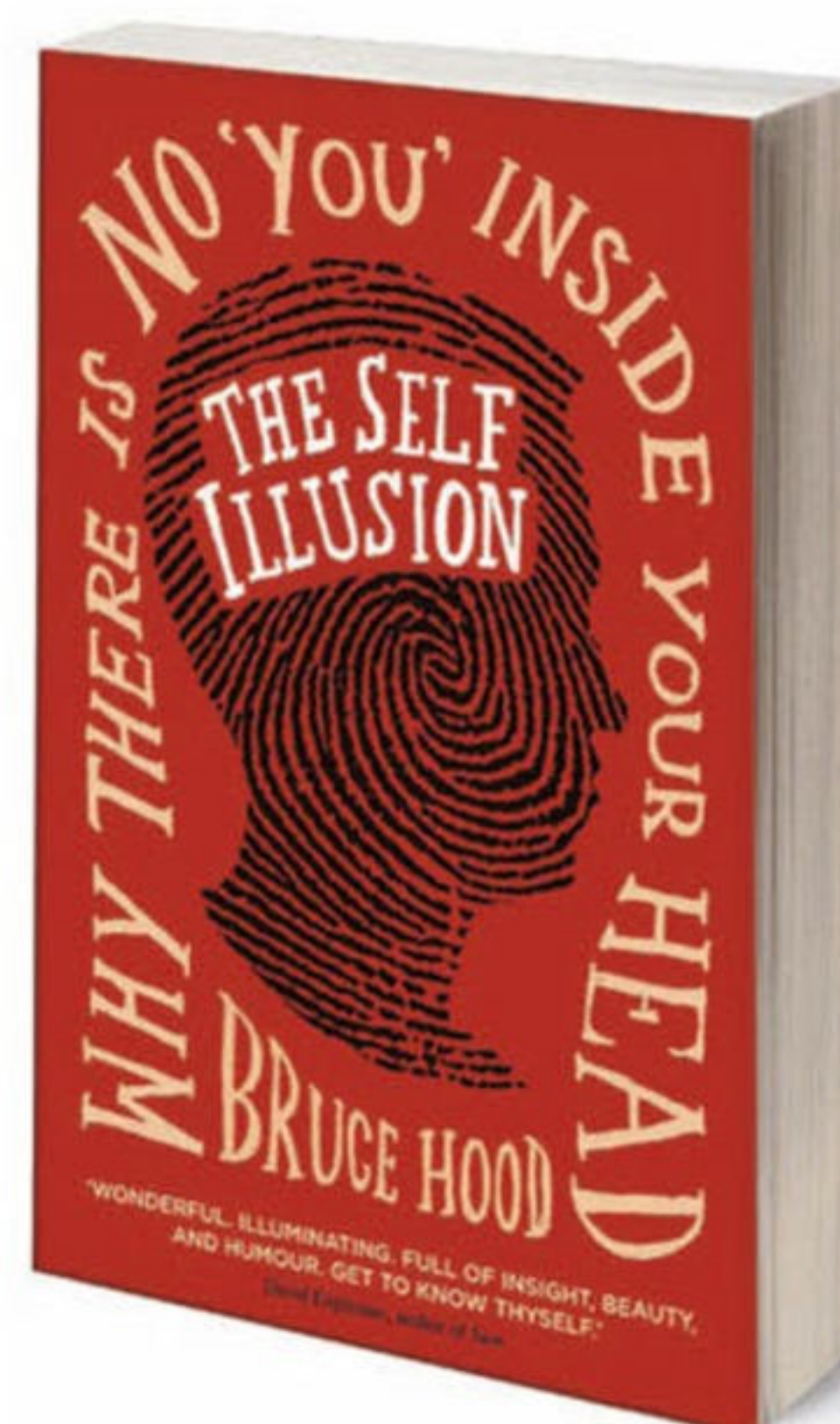
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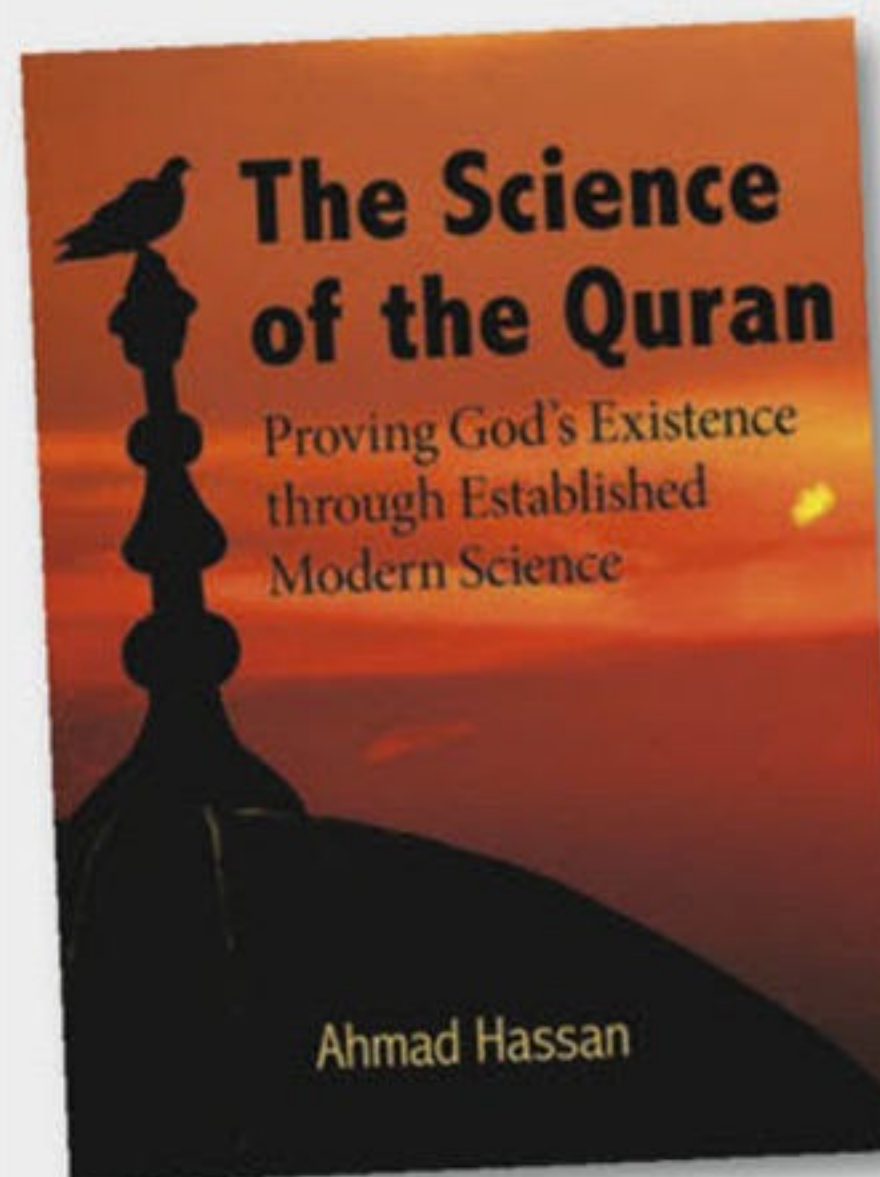
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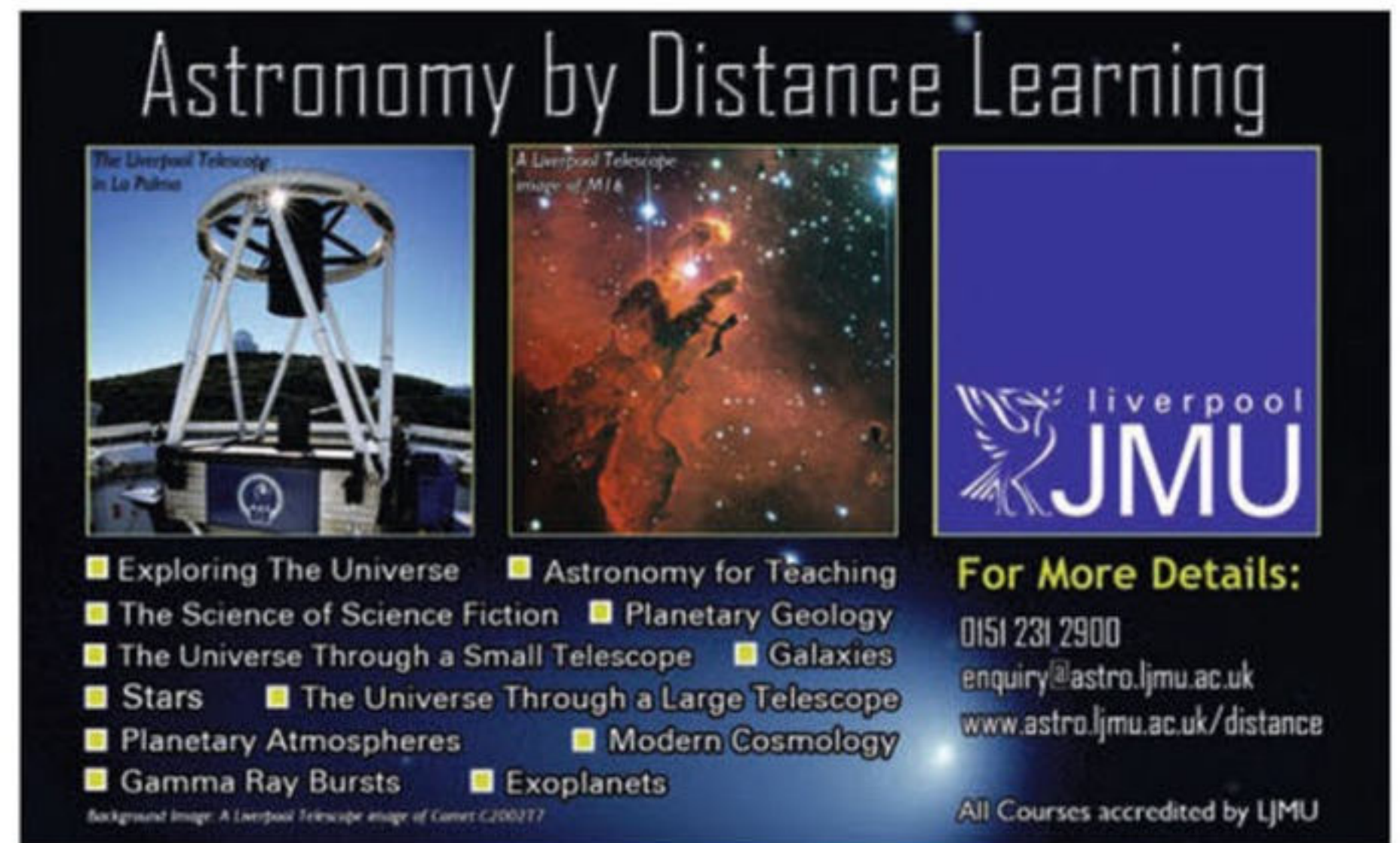
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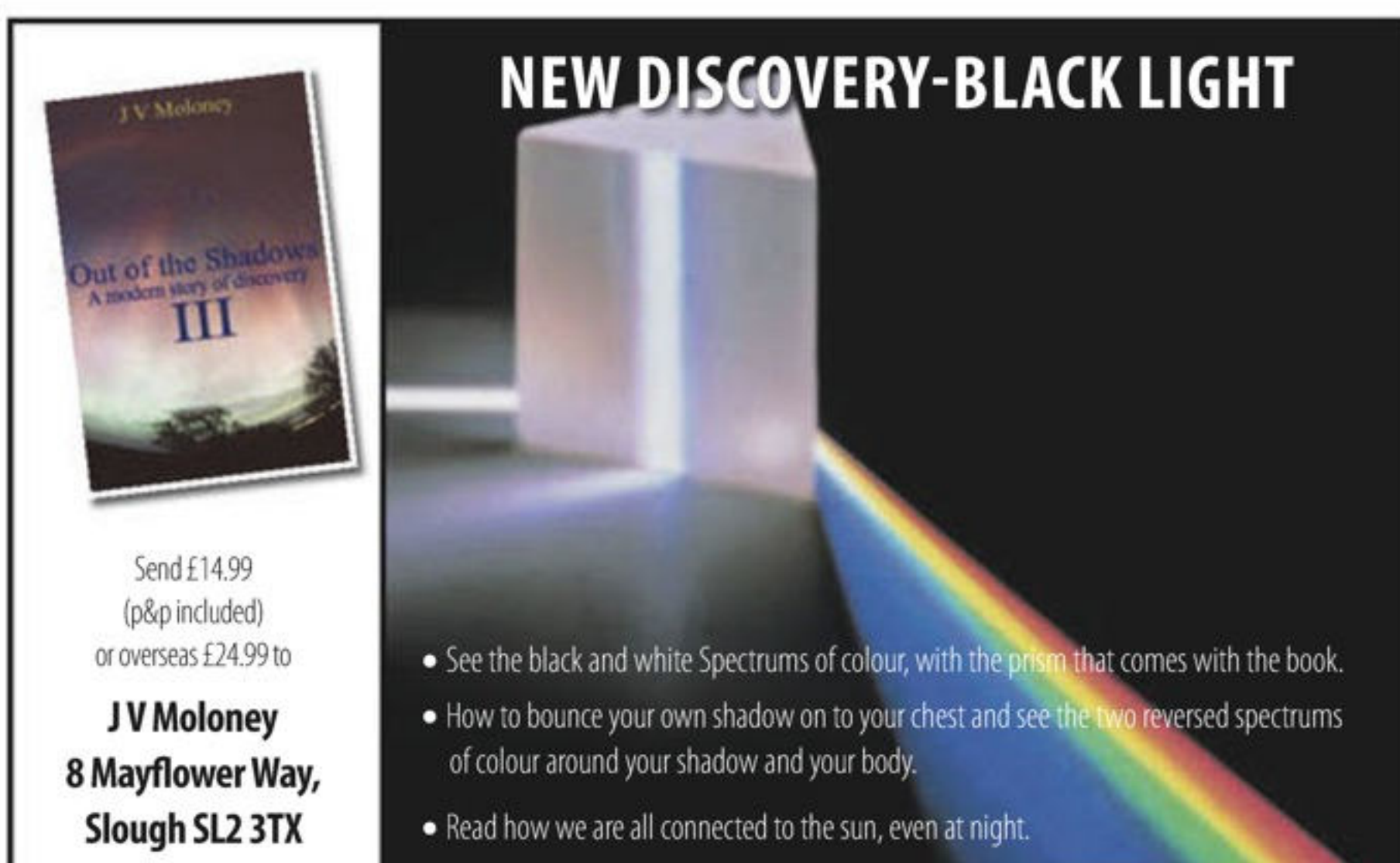
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Then, Now & Next

Fifty years ago,
a chance find led
astronomers to a
powerful new type
of celestial object

WORDS: ALASTAIR GUNN;
ILLUSTRATION: ANDY POTTS

◀ THEN

In June 1962, a group of US researchers led by Riccardo Giacconi were looking for X-rays from the Moon. Since X-rays are absorbed by the Earth's atmosphere, Giacconi and his team launched their instruments on rockets, sending them into space. During those few fleeting moments above the planet, the team's Geiger counters picked up what they were looking for.

However, the X-rays weren't from the Moon. Something far off in the cosmos, in the constellation of Scorpius, was pumping out unbelievable amounts of radiation. Whatever it was, its brightness in X-rays alone was 60,000 times the total luminosity of the Sun. It was dubbed Scorpius X-1 (Sco X-1), and within a few months, astronomers had found many more of these mysterious objects.

Giacconi's instruments, however, could not accurately pinpoint Sco X-1's location – it took a further four years to identify its optical counterpart: a very faint, unremarkable blue star.

|| NOW

Today, we know of several hundred objects like Sco X-1, both within our own Milky Way Galaxy and in others nearby – they're known as X-ray binaries. We know what they are, too, thanks to the launch of satellites in the 1970s to study X-rays. In an X-ray binary, matter is transferred between a 'donor' star and a compact companion – usually a white dwarf, neutron star or black hole. As matter is sucked into the compact object, friction heats it up to temperatures in excess of a million degrees, which releases huge amounts of energy, mostly in the form of X-rays.

NASA's Chandra X-ray Observatory has made great advances in detecting and imaging these powerful sources of radiation. They make ideal 'laboratories' for astronomers studying phenomena such as the evolution of stars, the physics of neutron stars and black holes, and the energy-generating capabilities of mass building up on celestial bodies.

▶▶ NEXT

X-ray binaries are still, however, one of the most varied and perplexing group of objects known to astronomy. We don't know how common compact stars are in the Universe, exactly how X-ray binaries evolve, or how they are related to some equally mysterious phenomena such as gamma-ray bursts and gravitational waves. As is always the case in astronomy, bigger and better telescopes will be needed to find out more about how these systems really work.

Unfortunately, though, we're in for a long wait. A joint NASA/ESA X-ray satellite called the International X-ray Observatory (IXO) is currently on hold. The most ambitious plan yet, an X-ray satellite called Generation-X, will have a collecting area of 50m² (1,000 times that of Chandra), but is unlikely to become a reality before 2035.

Nevertheless, 50 years after their initial discovery, astronomers continue to pursue the many secrets of these fascinating and enigmatic objects.



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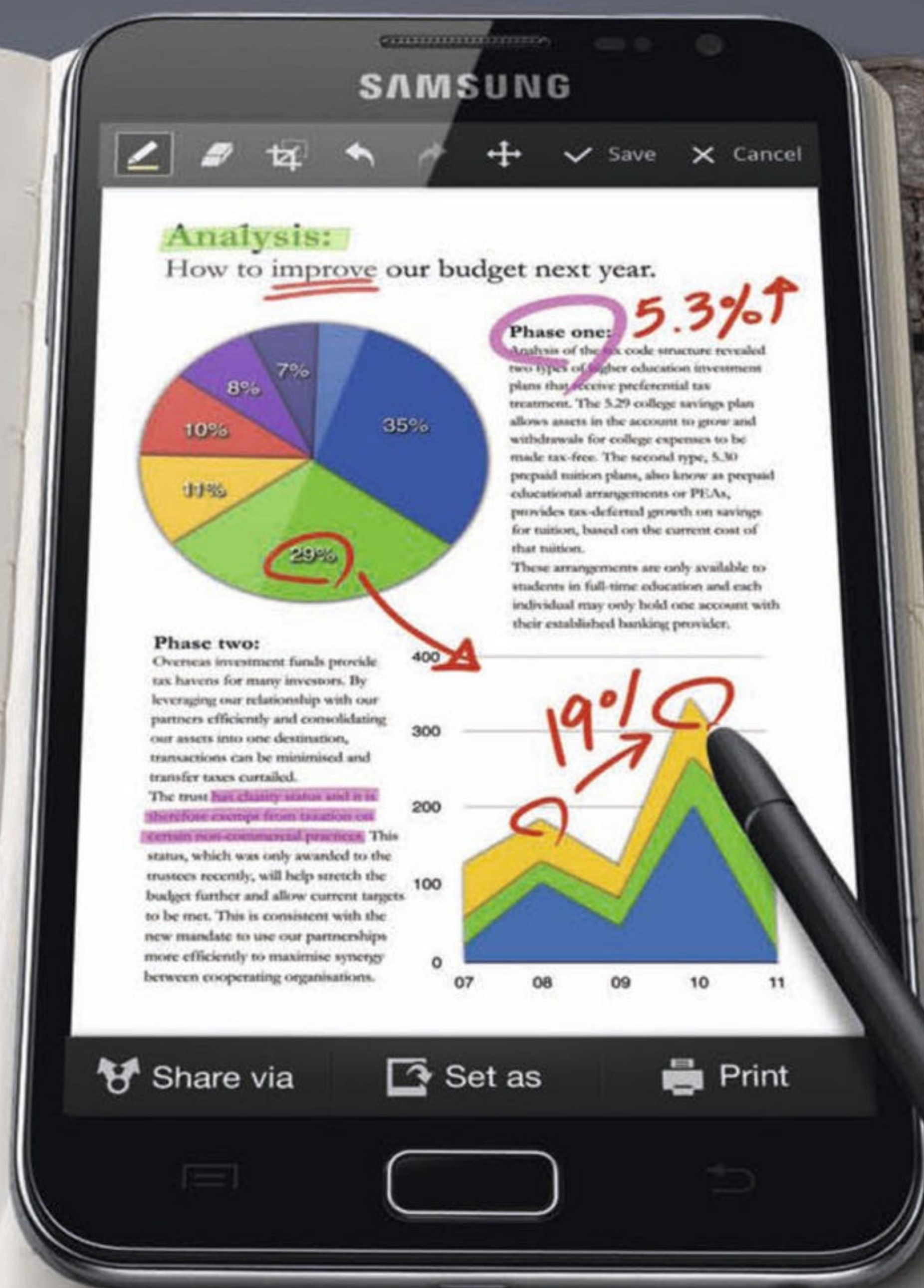
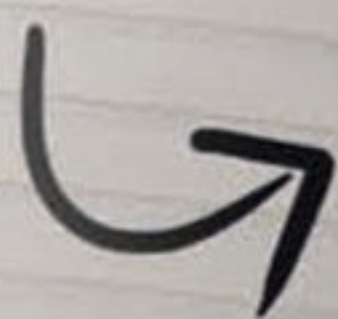
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